NEW ZEALAND INFRASTRUCTURE COMMISSION
Te Waihanga

Why do construction input costs change?

The role of global and local factors

Te Waihanga Research Insights series
December 2023

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New Zealand Infrastructure commission / Te Waihanga

Te Waihanga seeks to transform infrastructure for all New Zealanders. By doing so our goal is to lift the economic performance of Aotearoa and improve the wellbeing of all New Zealanders.

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Cut to the chase

We need to better understand what drives construction cost uncertainty

Planning and budgeting for large infrastructure projects can be like planning a picnic on a springtime day. Just when you think you've planned everything right and the forecast looks great, the weather shifts unexpectedly to rain. Near-term construction cost uncertainty can cause delays, require scope changes, and affect the viability of construction firms.

Rautaki Hanganga o Aotearoa, the New Zealand Infrastructure Strategy, recommends that in order to better achieve cost-effectiveness of our infrastructure investments, we need to develop a knowledge base of drivers and trends in construction costs.

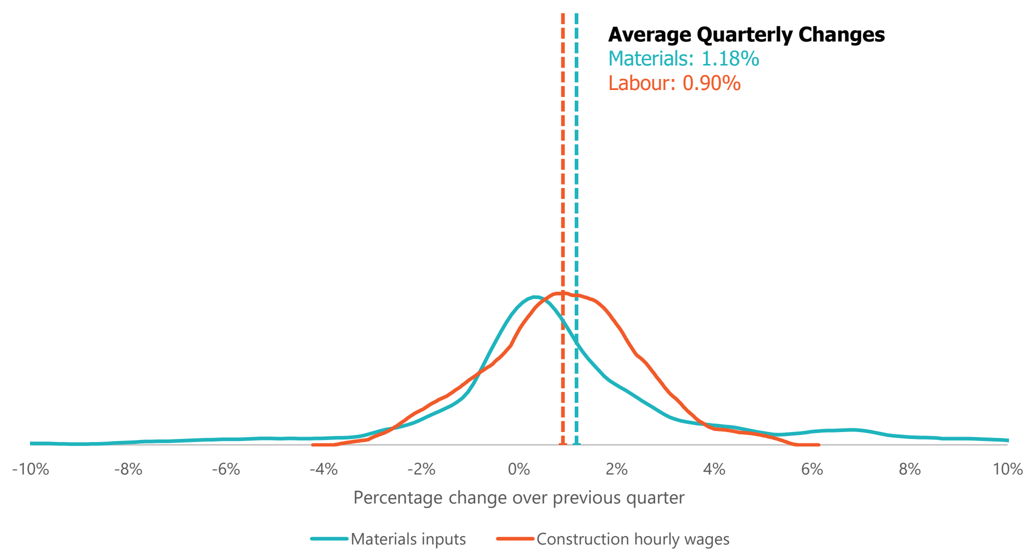
It's a well-known problem but we need to make it a well-understood problem too. If we better understood cost uncertainties for construction, we could better plan and mitigate those risks. This will ultimately lead to more cost-effective infrastructure construction, meaning we will get more infrastructure for the money we spend.

Construction input costs are rising and volatile

A construction project has several key costs. These include the wages paid to workers, the rental of equipment, and the materials (steel, wood, and paint, for example) used in construction. Since 2000, these construction input costs have consistently outpaced the costs to other industries in the economy. In fact, over that time period, no other industry has seen the costs of its inputs rise faster than construction.

Further, construction inputs costs are volatile, particularly material prices. In the 53 quarters since 2010, key material prices used in construction fluctuated more than 2% in a given quarter (in other words, +/- 8% change in a year) almost half the time.

Figure 2: Distribution of quarterly changes in construction input prices, 2010–2022



Source: SNZ Producer Prices Indices, Quarterly Employment Survey, 2020 National Account Input-Output tables, and Te Waihanga analysis

Both national and global factors are important for construction inputs

To learn more about what drives cost uncertainty in construction, we look at two of its most important inputs: labour and materials. Within infrastructure construction, direct labour and material inputs represent 22% and 17% of total infrastructure construction costs respectively.[1]

The four key findings from our research into what drives short-term fluctuations in these two key inputs are listed below.

1	**New Zealand economy-wide factors are important for understanding labour cost fluctuations but not material costs.**	Wages in construction track wages elsewhere in the economy. For material prices, we find little evidence that increased investment or strong economic conditions in New Zealand drive higher prices.
2	**Global factors play a significant role in material price fluctuations but not labour costs.**	Key material prices are correlated across countries, particularly for tradeable materials. Global commodity prices are highly predictive of our material prices, especially for structural steel, timber, and diesel fuel. Conversely, construction wages in New Zealand do not appear to be affected by Australian construction or economy-wide wages.
3	**Prices for both materials and labour adjust quickly.**	When construction wage growth is faster or slower than economy-wide wage growth, the gap is closed within a couple of years, rather than decades. For materials, changes in global prices are reflected in New Zealand prices almost instantly.
4	**Industry specific factors play a modest role for labour costs and a possible role in material prices.**	An especially tight labour market for construction workers may drive modestly higher construction wages temporarily, but not in the long run, as higher wages draw in more workers. For materials, local or industry-specific costs like transport costs or regional demand may put pressure on prices.

[1] The remaining share portion of costs is indirect, meaning the infrastructure construction sector subcontracting to other industries. These subcontractors would also have labour and material costs similar to the infrastructure construction industry.

We can control some cost drivers more than others

This *Research Insights* piece, together with our September and December 2022 reports, have built our knowledge base about trends, drivers, and comparative levels of construction costs in New Zealand.

These papers highlight the importance of three factors to the costs of infrastructure construction: input costs, productivity, and scope of the project.

Input costs	x	Productivity	x	Scope	=	Total costs
How do construction input costs move?		How efficiently do we use inputs to build infrastructure?		How complex is the infrastructure that we're building?		
(This RI paper)		*(September 2022 RI)*		*(December 2022 RI)*		

Each of these factors can influence construction costs over different periods of time. Input costs fluctuations, determined by material prices, shift every quarter, while productivity improvements happen over a span of decades.

We also need to consider the degree to which we have control over these factors so that we right-size our interventions.

We lay out our knowledge about each of these cost factors, when they might be important to construction costs, our ability to control them, and some examples of interventions we can take to mitigate their impact.

Factor	How fast can it change	How much influence do infrastructure providers or decision-makers have	Example interventions
Input costs – labour	Months	Limited	-Visa programmes for specific skills/roles -Identifying skills for training programmes -Addressing specific skill shortfalls
Input costs – materials	Months	Limited	-Better monitoring and forecasting of prices -Fixed price contracts and currency hedging
Productivity	Decades	High	-Promoting competition among firms -Openness to new innovations. -Standardisation of designs
Project scope / design	Years	High	-Stronger planning and problem definition frameworks -Consistent regulatory environments

From this framework, our research highlights that rather than a silver bullet, addressing infrastructure construction costs in both the short and long term will require a suite of solutions targeted at specific factors. The cumulative effect of these solutions will work towards greater quantity and quality of infrastructure, leading to an infrastructure system that lifts the economic performance of Aotearoa and improves the well-being of all New Zealanders.

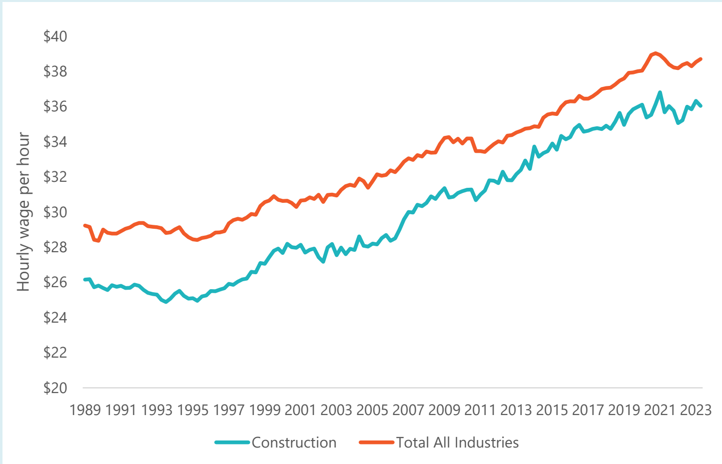
In depth: What drives construction labour costs?

Finding labour is an issue for construction firms, but it is also a problem almost everywhere. Surveys of firms expressing difficulty finding labour show the same findings for all firms as they do for those in the construction industry.

We also know that real (inflation-adjusted) wages in construction generally follow the same track as economy-wide wages (Figure 1). This suggests that the overall labour market is very important for determining wage growth in the construction industry.

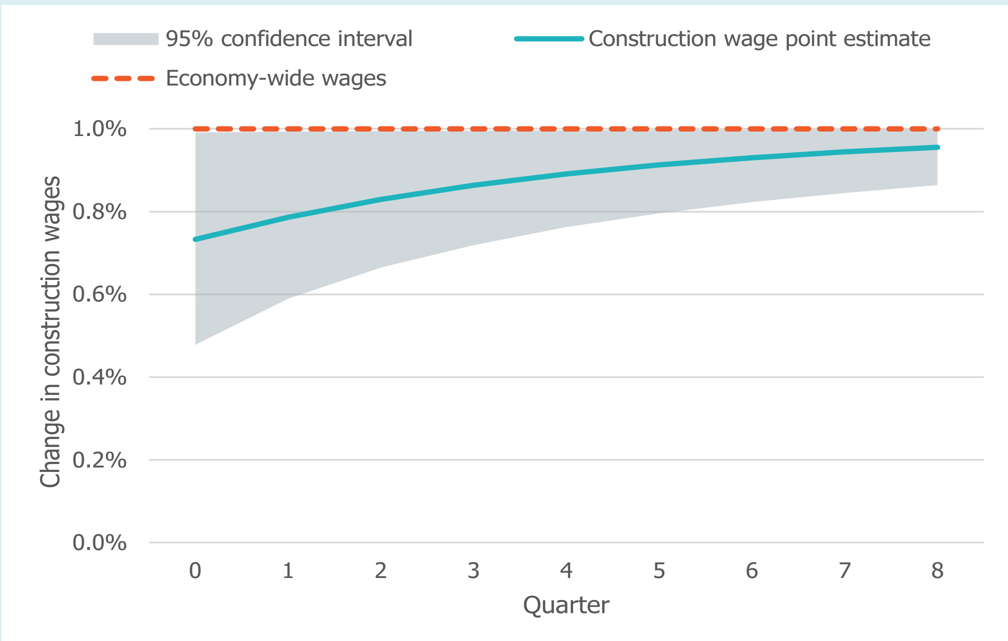
Our research confirms this initial impression:

Figure 1: Real (inflation-adjusted) average hourly wages in construction and the overall economy



- Overall economy wages drive construction wage growth in both the short and long term.
- Frictions, such as the time it takes to train new workers or occupational licensing, prevent this near-perfect relationship in the short run. This also means that short-term labour market tightness in construction can drive wages higher than economy-wide wages.
- Gaps in construction or economy-wide wage growth close relatively quickly (Figure 2). We shouldn't expect construction wages to put more long-term pressure on project costs beyond overall growth in wages.

Figure 2: Change in construction wages following a 1% increase in economy-wide wages



Source: Te Waihanga analysis – estimates are from Model 1 in the main body

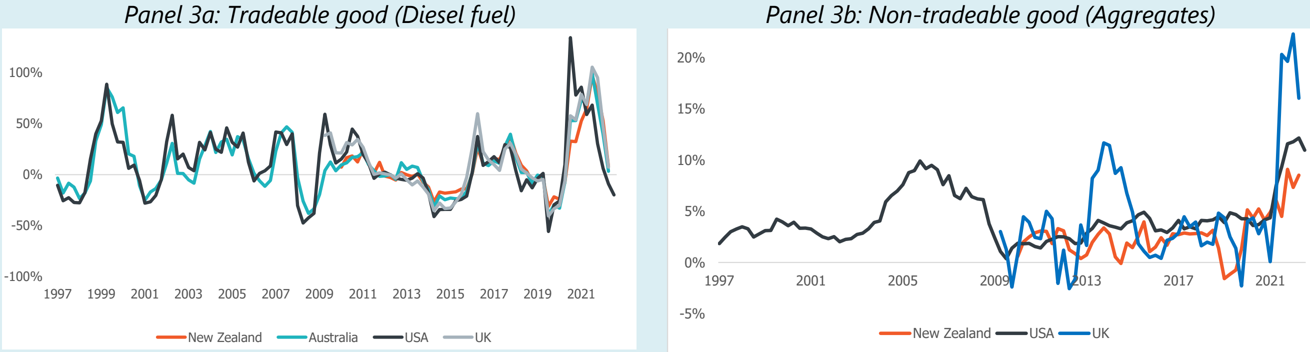
In depth: The impact of global factors on material prices

Material prices appear to closely track global movements in material prices. The relationship is particularly strong for materials that are highly tradeable. For materials with high transport costs, the relationship is weaker. This suggests that there are global phenomena that drive material prices in New Zealand (Figure 3).

Figure 3: Year-over-year price fluctuations in various construction inputs across countries

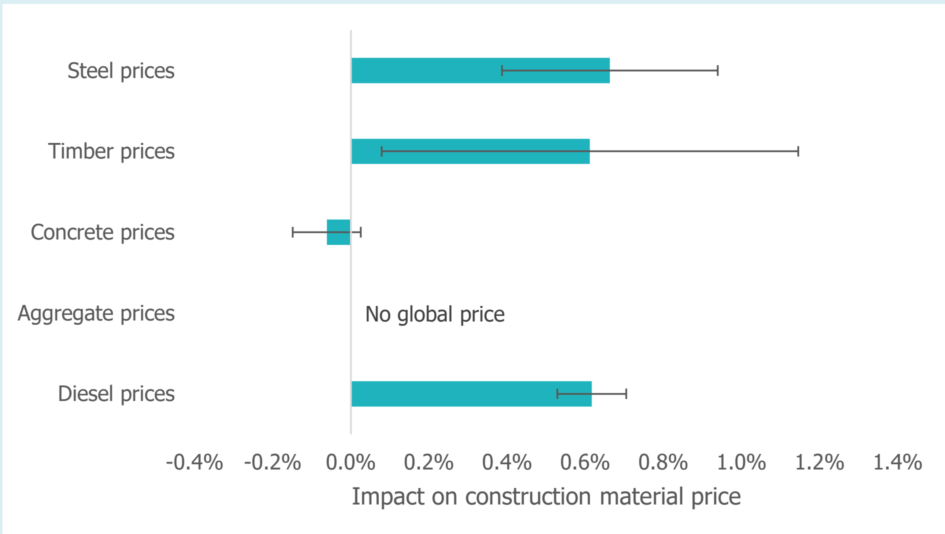
Panel 3a: Tradeable good (Diesel fuel)

Panel 3b: Non-tradeable good (Aggregates)



This paper finds that this is the case for key construction materials. Structural steel, timber, and diesel fuel prices in New Zealand are largely driven by the global price. For goods produced and sourced locally, like concrete and cement, proxies for global prices do not seem to matter (Figure 4).

Figure 4: Impact of a 1% increase in world commodity price on New Zealand material prices



Sources: SNZ, U.S. Bureau of Labor Statistics, Australia Bureau of Statistics, U.K. Office of National Statistics, and Te Waihanga analysis

Source: Size of bars reflects magnitude of long-run coefficients (or sum of all quarterly impacts) in the 'worldwide commodity price' row of Table 5. Error bars indicate 95% confidence interval.

Conversely, broad national-level demand factors, like a rapid scale up in investment (in either housing, infrastructure, or both) or strong economic conditions (as proxied by high levels of employment) do not appear to affect material prices in New Zealand. However, our analysis does not rule out that prices may respond to industry-specific or regional shocks. For example, aggregate demand for Transmission Gully Motorway forced the reopening of a local quarry to prevent supply delays and cost inflation.[1]

[1]https://www.fultonhoganquarries.com/post/crunch-time-for-nz-s-quarries-as-aggregate-price-soar

Contents

1. Introduction

1.1. Building high-quality infrastructure requires good bang for our buck

New Zealand faces significant infrastructure challenges. The costs of meeting demographic changes, responding to climate change and environmental shocks, as well as maintaining and improving our existing infrastructure, are large. Meeting this challenge will require a suite of solutions beyond simply spending more. We need better bang for our buck.

1.2. Achieving value for money requires better understanding of infrastructure costs

Rautaki Hanganga o Aotearoa, the New Zealand Infrastructure Strategy 2022– 2052, highlights that New Zealand needs to develop better frameworks to guide decision-making, strategic planning, and information collection. We also need more robust assessments of projects *ex ante* and *ex post*. A key step in this process is conducting rigorous and transparent cost-benefit analysis.

These analyses, however, are only as good as our ability to accurately estimate their components: costs and benefits.

Recommendation 46 in *Rautaki Hanganga o Aotearoa* speaks to this directly, advocating for advancing our knowledge base on the cost performance of New Zealand's infrastructure sector, including identifying cost trends and drivers of cost trends.

Our *Research Insights* series has worked to improve this knowledge base. Our September 2022 report explored how slow productivity growth in the heavy and civil construction sector led to higher prices in the long-term. Our December 2022 *Research Insights* piece benchmarked New Zealand's infrastructure delivery costs against other high-income countries. This report adds to this knowledge base by exploring the short-term drivers of construction cost inflation.

1.3. Why should we care about short-term changes in construction costs?

Although construction price inflation has been in the news recently,[2,3,4] construction costs have been outpacing economy-wide costs for the better part of the last 20 years (Table 1). This means we must pay more for the same amount of infrastructure over time. Our previous research has identified slow productivity growth in construction as a root cause of this issue.[5] In the long term, lifting productivity growth will be crucial for delivering high-quality infrastructure at a more affordable price.

[2] https://www.corelogic.co.nz/news-research/news/2023/annual-construction-cost-growth-hits-a-record-high-as-industry-slowdown-looms
[3] https://www.rnz.co.nz/news/business/487879/construction-cost-inflation-at-its-peak-survey
[4] https://www.rnz.co.nz/news/political/490070/mbie-to-monitor-building-supply-prices-ministers
[5] https://tewaihanga.govt.nz/media/fsbjr2fh/economic-performance-of-new-zealands-construction-industry.pdf

Table 1: Average annual growth rates in output prices for construction sectors

	Construction overall	Residential building construction	Non-residential building construction	Heavy and civil engineering construction	Construction services	Economy wide
1995 through 1999	1.0%	1.7%	0.8%	0.6%	0.8%	**1.0%**
2000 through 2008	4.4%	4.2%	3.7%	4.7%	4.3%	**3.7%**
2009 through 2019	2.5%	3.1%	2.4%	2.4%	2.2%	**1.7%**
2020 through 2023Q1	7.6%	9.3%	7.3%	7.8%	6.5%	**5.0%**

Source: Statistics New Zealand Producer Price Indices and Te Waihanga analysis[6]

However, short-term movements in construction prices are also important. For infrastructure projects in the procurement or delivery phases, changing construction prices can have a major impact on project time and cost budgets (Musarat and Alaloul, 2020). We also know that rapid cost inflation can affect the viability of construction firms.[7] It is therefore critical to have a good, evidence-based understanding of how rapidly short-term prices can change and what factors cause prices to rise.

1.4. We focus on the main inputs to infrastructure construction

There are three main types of inputs to the construction of an infrastructure project:

- ***Labour inputs:*** wages paid directly to construction workers and other specialised types of labour like civil engineers, some of whom work for subcontractor firms who supply services to the lead contractor
- ***Material inputs:*** the cost of materials like steel, concrete, and aggregate
- ***Machinery and equipment inputs:*** the costs of physical capital used in construction like cranes, tunnel boring machines or excavators.

Table 2 shows the composition of inputs to infrastructure construction projects, using Statistics New Zealand (SNZ)'s input-output tables for the heavy and civil construction industry. Our research primarily focuses on labour and material inputs.

This data shows that direct labour inputs represent around 22% of infrastructure construction costs. Direct inputs of construction materials are about 17% of total costs. The five most important construction material inputs, by value, are structural metal, aggregates, concrete, diesel, and plaster/paperboard products.[8] These materials account for around 13% of total costs. Direct equipment and machinery inputs are around 10% of total costs.[9]

In addition to these direct inputs, costs for labour and materials are also embedded into other intermediate service inputs. While most of this work is likely labour focused (such as 'installation work') it could include a sizeable material share. For instance, firms providing civil engineering

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[6] The cost growth shown in the Producer Price Index is also generally confirmed by Statistics New Zealand's Capital Goods Price Index (CGPI). The CGPI measures the price changes in physical assets that various industries produce.
[7] https://www.macrobusiness.com.au/2023/03/unprecedented-cost-squeeze-pushes-home-builders-into-insolvency/
[8] These shares are broadly in line with data from Australia which found that labour costs are between 25% and 30% of *project costs* (not industry output costs), intermediate inputs are between 35% and 50%.
[9] We categorised roughly 70 inputs for heavy and civil infrastructure into 3 categories: material, equipment, and services. Materials were defined as inputs that were generally used in the construction of a tangible good (such as paint, steel, wood). Equipment was categorised as inputs used to make those goods (such as vehicles, rental equipment), and services generally included the name 'service' within their category name.

services (an intermediate service input) will have labourers, but they will also use diesel to deliver construction materials like aggregates.

Table 2: Key inputs into heavy and civil construction

Input	Share of total industry inputs	Category total
Direct material inputs		
Structural metal products and other fabricated metal products	3.7%	17.6%
Sands, pebbles, gravel, clays, stone and bitumen	3.4%	
Concrete, and other non-metallic mineral products	2.5%	
Diesel	1.7%	
Plaster and lime, other and paperboard products	1.6%	
Wood products	0.6%	
All other material inputs	4.0%	
Direct equipment inputs		
Consumption of capital	3.8%	10.1%
Maintenance of other equipment	2.1%	
Equipment hire services	1.7%	
All other equipment inputs	2.5%	
Direct labour Input (compensation of employees)		
Intermediate service inputs		
Civil engineering services	16.8%	41.8%
Other installation work	13.5%	
All other service inputs	11.4%	
Taxes, subsidies, margins	8.0%	8.0%
Total		**100%**

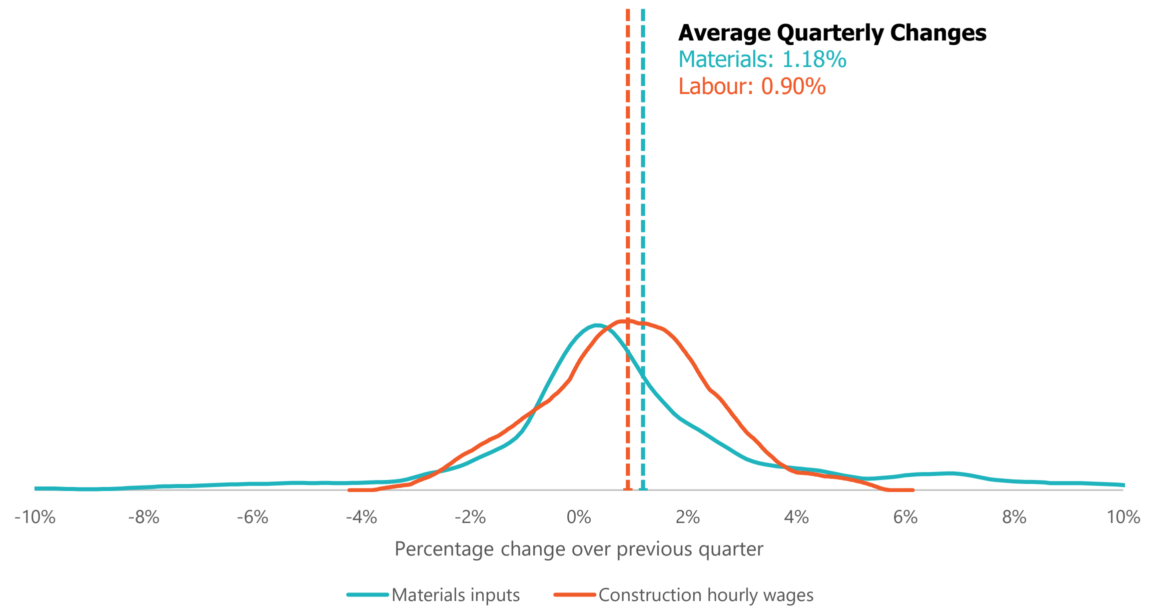
Source: SNZ 2020 Input-Output tables and Te Waihanga analysis

Figure 1 illustrates the distribution of quarterly price changes for construction material inputs, service inputs, and wages.[10] We find that construction materials exhibit significantly more volatility than services inputs or labour costs. It is reasonably common for material prices to increase or decrease more than 5% in a single quarter, but extremely uncommon for service input (which are labour heavy) prices or construction wages to change that rapidly.

[10] For this analysis, we matched the intermediate inputs from the Input-Output tables to their Producer Price Index or Capital Goods Price Index series and calculated quarterly growth rates. For compensation of employees, we used the nominal hourly wage for the construction industry. We then calculated smoothed kernel density plots (using an Epanechnikov kernel) for each set of inputs.

On average, construction material prices rise more rapidly than either construction wages or services input prices. This suggests that if we are concerned with short-term price movements, we should look first at material price volatility, while labour costs (wages and benefits) put steadier upward pressure on construction costs.

Figure 1: Distribution of quarterly changes in construction input prices, 2010–2022



Source: SNZ Producer Price Indices, Quarterly Employment Survey, 2020 National Account Input-Output tables, and Te Waihanga analysis. Price changes are calculated in nominal terms, i.e., not adjusting for inflation. Vertical lines show average (mean) quarterly changes.

1.5. Building the evidence base

In this *Research Insights* paper, we focus on short-term movements in prices for key inputs to construction, in particular construction wages and construction material prices.[11] Specifically, we address the following key research questions:

- **What drives changes in construction wages?** In the short term, is wage growth in the construction sector mostly a function of the supply and demand for workers in the sector or does it mostly track the overall economy-wide labour market? When construction labour costs spike, how quickly do labour markets adjust?
- **How important are local versus global factors for material input costs?** How do the price movements in key construction materials mimic those of other countries? How do various foreign and domestic variables affect price movements in the short term?

[11] Plant and equipment costs are also important input costs to a construction project. These costs are not a focus of this paper but could be an avenue for future research.

2. What drives increases in construction wages?

Construction labour is one of the main inputs to infrastructure delivery. In this section, we examine the factors that affect construction wages in the short and long term. We analyse the impact of factors that are specific to the construction industry, like challenges finding construction workers, and the impact of broader national factors, like wages elsewhere in the New Zealand economy, or international factors, like wages in the Australian construction sector.

2.1 The construction labour market in context

It's hard to find workers… but not just in construction

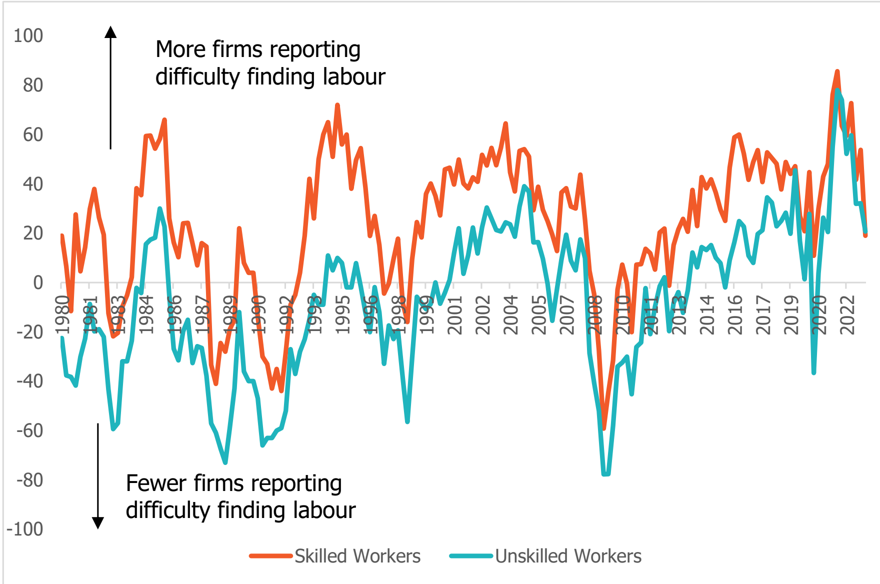
In recent years, surveys of construction firms have highlighted acute challenges to finding workers. New Zealand Institute for Economic Research's (NZIER) Quarterly Survey of Business Opinion (QSBO) reports construction firms are having difficulty finding all types of labour, although the pressure seems to be easing recently (Panel A in Figure 2). This is consistent with results from other construction sector and job opening surveys.[12,13,14]

However, labour market tightness in construction sits in an overall context of a labour shortage across all industries. The same QSBO survey shows that across the economy, all firms report a similar level of difficulty finding labour (Panel B in Figure 2). This pattern has held true over the last four decades: construction firms tend to have a harder time finding labour when firms elsewhere in the economy are reporting similar challenges, and vice versa.

[12] https://civilcontractors.co.nz/filescust/CMS/Documents/CCNZ%20Teletrac%20Navman%20Construction%20Industry%20Survey%20Report%202022_final.pdf
[13] https://www.bdo.nz/getmedia/581e38ab-eca6-44b9-9a93-6984725c9c13/BDO-Construction-Sector-Report-2023-FINAL.pdf
[14] https://www.mbie.govt.nz/business-and-employment/employment-and-skills/labour-market-reports-data-and-analysis/jobs-online

Figure 2: Net share of firms reporting difficulty finding labour

Panel A: Construction firms



Panel B: All firms

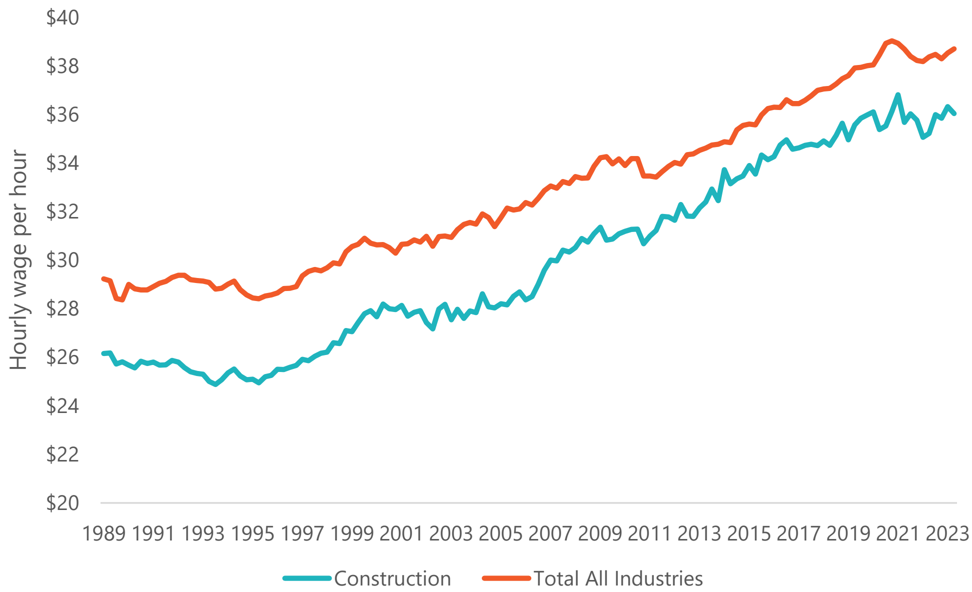
Source: NZIER, Quarterly Survey of Business Opinion

Construction wage growth tracks economy-wide wage growth

Using a basic supply and demand framework, we would expect employers to increase compensation (including pay and benefits) to attract and retain workers when labour is scarce. In a tight labour market, workers also have the power to ask for raises or change jobs to earn more. At any given point in time, we would expect construction wages to grow faster than wages elsewhere in the economy if it was unusually difficult to find construction workers and difficult to recruit and train new workers with the required skills.

However, **Figure 3** shows that, since 1989, real (inflation-adjusted) construction wages and economy-wide wages have tracked each other closely. Average construction wages are lower than economy-wide average wages, but both tend to increase in line with each other. While the wage gap grows or shrinks slightly from time to time, we do not see any sustained, long-term changes to this pattern.

Figure 3: Real (inflation-adjusted) average hourly wages in construction and the overall economy



Source: Te Waihanga analysis of SNZ Quarterly Employment Survey

Workers move rapidly in and out of the construction industry

There is evidence that the New Zealand construction industry scales up rapidly to meet increased demand.[15] Other research shows that the industry is very reliant on attracting new and existing workers from the New Zealand labour force to meet labour needs. Workers frequently transition into and out of the construction industry.

The share of all New Zealand workers working in construction has increased in recent decades: from 8% of total employment in 2009 to over 10% in 2023. This is mostly due to recruitment from elsewhere in the New Zealand economy. Productivity Commission research found that although migrants have played a growing role in the construction labour force over time, they are still a relatively small share of overall workers (Schiff, 2022).

Coleman and Zheng (2020) analysed workers' transition rates between industries over the 2000–2018 period. On average, they found that 18.8% of construction workers had not been working in the sector 12 months earlier which is roughly on par with the economy as a whole. These findings are reinforced by evidence from the supplementary September quarter *Research Insights* paper Te Waihanga published on the infrastructure construction workforce, which finds that, in 2018, 40% of the workforce had less than two years of tenure in their current industry. Inter-industry mobility was higher among 'blue-collar' roles such as labourers and road traffic controllers, which make up a significant part of the workforce.

[15] At the detailed industry level, building construction and construction services have experienced more rapid increases in labour input than heavy and civil engineering construction. This suggests that infrastructure construction may be 'stickier' than other types of construction.

2.2 Our approach to explaining construction labour costs

Our analysis of movements in construction wages is motivated by two key questions.

Is there a long-run relationship between construction wages and wages elsewhere in the economy? Previous research on the subject has found a high degree of worker mobility between the two sectors. Inflation-adjusted wages between the two sectors appear to move together with some divergences depending upon the time-period. This suggests that if construction wages grow faster in construction, an influx of new workers may put downward pressure on wage growth in the long term. Conversely, if wages grow faster in other industries, construction firms may need to respond by increasing wages to keep the workers they already have.

Is there any evidence of short-run frictions that make it difficult to adjust to the long-run relationship? Frictions prevent the immediate adjustment of wages between the two sectors to their long-run relationship. Examples include the time and effort it takes to train new workers, regulations and licensing requirements for workers, and the relocation of workers. If there are short-term frictions, we might expect to see measures of labour market tightness driving higher construction wages in the short term, even after controlling for economy-wide factors.

Finally, if there are frictions that prevent immediate adjustment of wages in the short run, we are also interested how it will take to return to a long-term wage relationship between the sectors.

We test these questions using econometric analysis in the following section.

2.3 Explaining changes in construction wages

In the long run, construction wages closely track economy-wide wages

Figure 3 above suggests that real wages in construction are related to wages elsewhere in the economy. In Appendix A, we test this apparent relationship for cointegration, a statistical concept that identifies whether there is a long-run equilibrium relationship between two or more variables. We find a strongly cointegrated relationship.[16] Although construction wages might grow faster or slower than economy-wide wages for short periods of time, wages have tended to return to their long-run equilibrium before long.[17]

This suggests that the construction labour market is closely linked with the overall New Zealand labour market. In the long run, construction wages are set based on the supply of and demand for labour in the New Zealand economy as a whole, rather than factors that are specific to the construction market.

[16] We used the Engle Granger two-step method for cointegration using a regression on logged real construction and economy-wide wages in levels and find a test statistic of -4.346, rejecting the hypothesis of no cointegration at the 1% level.

[17] We used real average hourly wages for this modelling as opposed to Statistics New Zealand's Labour Cost Index (LCI) for this analysis primarily because the wage series begins in 1989 versus 2009 for the LCI. The inclusion of multiple business cycles is beneficial for determining drivers of wage divergence. Moreover, unlike real wages, the LCIs for construction and the economy did not have a cointegrating relationship (Engle Granger test statistic of -1.096) so a different model type would need to be considered.

We explore short-run and long-run drivers of construction wages

Table 3 summarises results from two time series econometric models that analyse short-run and long-run drivers of growth in average hourly construction wages. These models are explained in further detail in Appendix A.

Model 1 shows the relationship between construction wage growth and economy-wide wage growth, without controlling for any other factors. The short-run coefficient on real economy-wide wages (0.73) indicates that when economy-wide wages rise by 1%, construction wages tend to immediately rise by 0.73%. The convergence factor of -0.21 indicates how fast the remaining gap in wages is closed. In this instance, the gap is closed by 21% in a single quarter. We expand on this convergence factor in the succeeding findings.

Model 2 adds some additional explanatory variables that test the short-run and long-run impact of labour tightness in construction (QSBO measure of difficulty finding construction labour) and the economy as a whole (QSBO economy-wide measure), as well as a control for overall economic growth (real GDP). These variables help us understand the role of short-run frictions in determining construction wages.

While these models help us understand the relationship between construction wages and economy-wide wages, they do not perfectly explain fluctuations in construction wages.[18] This highlights the complex nature of wage growth and the potential for other, unmeasured factors to play a role.

[18] As indicated by R-squared values – an R2 value of 0.39 indicates that a statistical model accounts for 39% of the variation in the outcome variable.

Table 3: Construction wage responses in response to a 1% change to economy-wide wages and other variables.

Quarterly changes in construction wages in response to a 1% changes the following variables

	Model 1		**Model 2**	
	Coefficients	**Std Errors**	**Coefficients**	**Std Errors**
Short Run				
Real economy-wide wage	0.733***	0.129	0.594***	0.152
QBSO: Difficulty finding construction labour			0.008***	0.003
Lagged one quarter			0.005**	0.002
QBSO: Difficulty finding economy-wide			-0.003	0.005
Lagged one quarter			0.100*	0.117
Long Run				
Real economy-wide wage			0.257	0.397
QSBO: Difficulty finding construction labour			-0.040**	0.018
QSBO: Difficulty finding labour economy-wide			0.009	0.172
Overall GDP			0.467**	0.178
Convergence factor	-0.210***	0.054	-0.206***	0.064
R-squared	0.24		0.39	

*Note: ***,**,* Denotes statistical significance at 1%, 5%, and 10% level. Figures in parentheses indicate standard errors. Results are from standard error correction model for Model 1 and an autoregressive distributive lag model with an error correction for Model 2. See Appendix A for more detail.*

We find evidence of short-run frictions that can cause construction wages to diverge …

Two key pieces of evidence suggest the existence of short-run frictions that can cause construction wages to grow faster or slower than economy-wide wages for a short period of time.

First, the correlation between construction wages and economy wages is not one-to-one in the short run. A 1% increase in economy-wide wages does not fully and immediately pass through to construction wages, which suggests that there are some factors that slow down adjustment in construction wages.[19]

Second, in the short run, construction wages rise faster in the short run when the construction labour market is tighter, as indicated by construction firms' self-reported difficulty finding labour. Short-run coefficients in Model 2 indicates that a one standard deviation increase in the share of construction firms reporting difficulty finding labour is associated with an 0.7% increase in real construction wages after one quarter and a further 0.5% increase in the following quarter.[20] However, labour tightness elsewhere in the economy does not affect construction wages.

[19] In Model 2, the long-run coefficient on economy-wide wages is smaller and not statistically significant, while the long-run coefficient on real GDP growth is larger and more statistically significant. The coefficient on real GDP (0.47) is similar to the labour share of income in the measured sector of the New Zealand economy (Conway, Meehan, and Parnham, 2015). https://www.productivity.govt.nz/assets/Documents/the-labour-income-share-in-new-zealand/e6a1d17058/Report-The-labour-income-share-in-New-Zealand.pdf

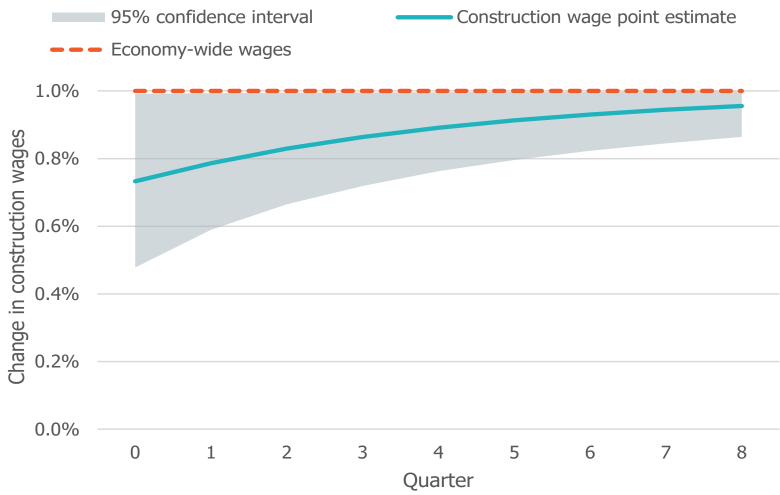
[20] The QSBO measures are in logged percentages. We calculate the impact of a one standard deviation in the QSBO measure, relative to the mean level for this series. The mean value for the QSBO survey is 14% of firms reporting difficulty finding labour, and the standard deviation is around 12.9%. We therefore calculate the impact of a one standard deviation increase by multiplying the relevant regression coefficient by 12.9%/14%. Interestingly, the long-run coefficient on construction labour tightness is negative, rather than positive. One potential interpretation is that this may be due to a composition effect: if construction firms face persistently tight labour conditions, they may respond by hiring less-experienced workers, who tend to earn lower wages than more-experienced workers.

... but adjustment to the long-run equilibrium happens in a year or two, rather than decades

When growth in construction wages is faster or slower the economy as a whole, wages adjust relatively quickly. Models 1 and 2 indicate similar convergence factors of around -0.21. What this means is that, when construction wages and economy-wide wages deviate from their long-run equilibrium, 21% of the gap closes every quarter.

Figure 4 illustrates how construction wages typically converge to their long-run relationship with economy-wide wages over time. A 1% increase in economy-wide wages initially leads to a 0.73% increase in construction wages. Over the course of two years, the remaining gap is closed such that construction and economy-wide wages return to their long-run equilibrium.

Figure 4: Change in construction wages following a 1% increase in economy-wide wages



Source: Te Waihanga analysis – estimates are from Model 1

Construction wage growth in Australia doesn't affect construction wages in New Zealand

Appendix A presents further analysis of the relationship between construction wages in Australia and New Zealand. While other research suggests that relative economic performance influences overall immigration between Australia and New Zealand,[21] changes to Australian construction wages do not appear to affect construction wages in New Zealand. The short-run relationship between Australian and New Zealand construction earnings growth in a given quarter is weak and, counterintuitively, negative.[22]

This suggests that New Zealand construction wages are largely determined by New Zealand-specific factors, rather than international factors.

[21] Jed Armstrong and Chris McDonald, Why the drivers of migration matter for the labour market. RBNZ analytical note AN2016/02, available at https://www.rbnz.govt.nz/hub/publications/analytical-note/2016/an2016-02
[22] Results and additional details in Table A6 in Appendix A.

3. What drives construction material price inflation?

Construction materials account for a large share of the costs of infrastructure delivery. Construction material prices tend to be more volatile than other input prices, meaning that it is important to understand what is driving price changes and what we can expect in the future.

In this section, we examine short- and long-term drivers of price inflation for the five most important infrastructure construction materials: Structural steel, aggregates, concrete and cement products, diesel, and timber. We analyse the impact of global factors, such as exchange rates and global commodity prices, and broad national factors, like changes in New Zealand's infrastructure and housing investment.

Previous research suggests that there is a link between economy-wide price inflation and material price inflation (Musarat, Alalou et al, 2020, Tran and Tookey, 2011). Fluctuations in material prices have been linked with cost and schedule overruns for construction projects (Olatunu, Orundami et al 2018; Mahamid, 2018; Memon et al, 2011; Frimpong et al, 2003). Material bottlenecks in construction have been linked to higher costs via lower productivity (Soekiman et al, 2011).

3.1 Construction materials in context

Materials used in infrastructure construction in New Zealand

We focus on the five most important heavy and civil construction materials: structural steel, aggregates, concrete and cement, diesel fuel, and timber. **Table 2** showed that these materials contribute around 13% of the direct costs to infrastructure construction, and a higher share once the cost of materials used by subcontractor firms are considered. These materials account for three-quarters of all material inputs to infrastructure construction. We measure price changes in these inputs using the producer price index or capital goods price index equivalent.[23]

Some construction materials are traded global, and others are traded locally

New Zealand is a small economy that trades heavily with other countries. However, some construction materials are more 'tradeable' than others. **Table 4** shows that New Zealand imports a significant amount of timber, petroleum products, and structural iron and steel, while importing negligible volumes of cement and aggregates.

[23] We use the following series:
Structural steel: Capital Goods Price Index, 'Structural metal products and parts thereof'
Aggregates: Producer Price Index – Input Series, 'Aggregates'
Concrete and cement: Producer Price Index – Input Series, 'Articles of concrete, cement, and plaster'
Diesel: Producer Price Index – Input Series, 'Diesel'
Timber: Producer Price Index – Input Series, 'Wood and timber'.
Note that there are some differences between the definitions used in SNZ's Input Output tables and the definitions used in SNZ's price indices. For instance, SNZ's Input Output tables include a category for 'sands, pebbles, gravel, clays, stone, and bitumen', while Producer Price Indices include an 'aggregates' category that includes sands, pebbles, gravel, etc, but excludes bitumen.

Table 4: New Zealand imports of key construction materials (millions USD)

Year	Timber	Cement, concrete, clinker	Aggregate	Refined and crude petroleum	Structural iron and steel
2011	$172.5	$21.5	$0.6	$7,880.0	$90.7
2012	$152.4	$20.2	$0.4	$6,654.0	$69.7
2013	$170.4	$25.6	$0.6	$6,568.7	$82.6
2014	$199.6	$34.8	$0.9	$6,283.2	$116.9
2015	$204.0	$32.7	$0.7	$3,555.9	$110.2
2016	$221.4	$29.5	$0.5	$2,978.4	$128.8
2017	$249.6	$33.4	$0.7	$3,681.5	$157.2
2018	$281.5	$40.8	$0.5	$5,157.2	$173.3
2019	$279.9	$42.7	$0.7	$4,556.1	$170.4
2020	$262.2	$43.0	$0.6	$3,016.3	$155.3
2021	$447.9	$69.6	$1.0	$3,801.9	$231.9
2022	$497.7	$59.1	$1.1	$6,022.9	$235.4

Source: UN Comtrade Database, HS codes 2517, 2523, 2709, 2710, 44, 7308, 6810

Trade patterns reflect the fact that construction materials have different supply chains and supply characteristics.[24]

Construction materials like structural steel, timber, and diesel are comparatively tradeable. These commodities are more valuable, relative to their weight, and easier to ship long distances. In particular:

- While New Zealand does produce some steel, the majority of fabricated structural steel is imported. Global demand for steel is important for steel pricing in New Zealand, and the steel or products produced locally have no impact on global prices.
- Imports of sawn timber are small in New Zealand (less than 3% of domestic demand). However, timber in New Zealand is export-facing markets meaning it is exposed to changes in global timber prices.[25]
- Refined petroleum products, including diesel fuel, are all imported since the closure of the Marsden Point refinery. Prior to that, we imported and refined crude oil and also imported refined petroleum products. While we do produce some crude oil, it is refined elsewhere. In 2022, diesel fuel was the most imported petroleum product, followed by petrol.[26]

By contrast, construction materials like aggregates and concrete are less tradeable. These commodities are less valuable, relative to their weight, and harder to ship long distances. In particular:

- Aggregates are usually quarried and supplied at a regional level. Transport prices for aggregates are as important as the price of the rock itself. Rapid expansions of quarrying capacity are difficult and time-consuming, so regional supply shortages are persistent in some areas of the country.
- 62% of New Zealand's cement is supplied locally, while the rest is imported. Importing cement requires specialised equipment and economies of scale. Ready-mixed concrete, which is produced at batching plants by mixing cement and aggregates, is characterised by highly regionalised markets as it can only be transported for 90 minutes.

[24] Infrastructure Resources Study by Te Waihanga, November 2021, https://tewaihanga.govt.nz/media/ayxfshpg/infrastructure-resources-study.pdf

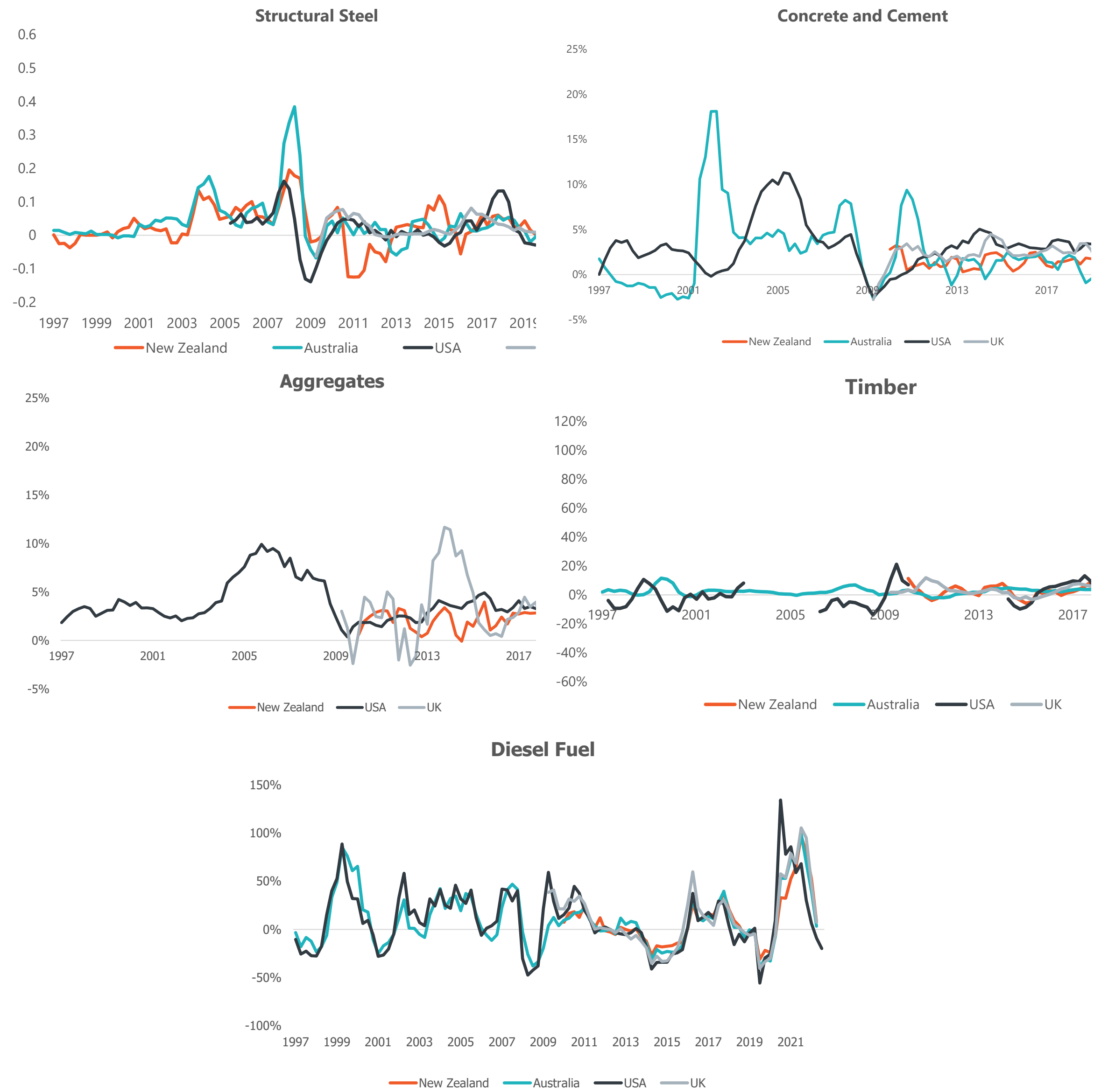
[25] https://tewaihanga.govt.nz/media/ayxfshpg/infrastructure-resources-study.pdf

[26] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics/

Price changes for construction materials are correlated between countries

Figure 5 shows material price growth for New Zealand and three other English-speaking countries with comparable price indices.[27] These charts suggest that construction material price movements are positively correlated across countries.[28] Moreover, prices for all construction materials spiked in all four countries following the COVID-19 pandemic, highlighting the global dimension to commodity prices.

Figure 5: Year-over-year price fluctuations in various construction inputs across countries



Sources: SNZ, U.S. Bureau of Labor Statistics, Australia Bureau of Statistics, U.K. Office of National Statistics, and Te Waihanga analysis

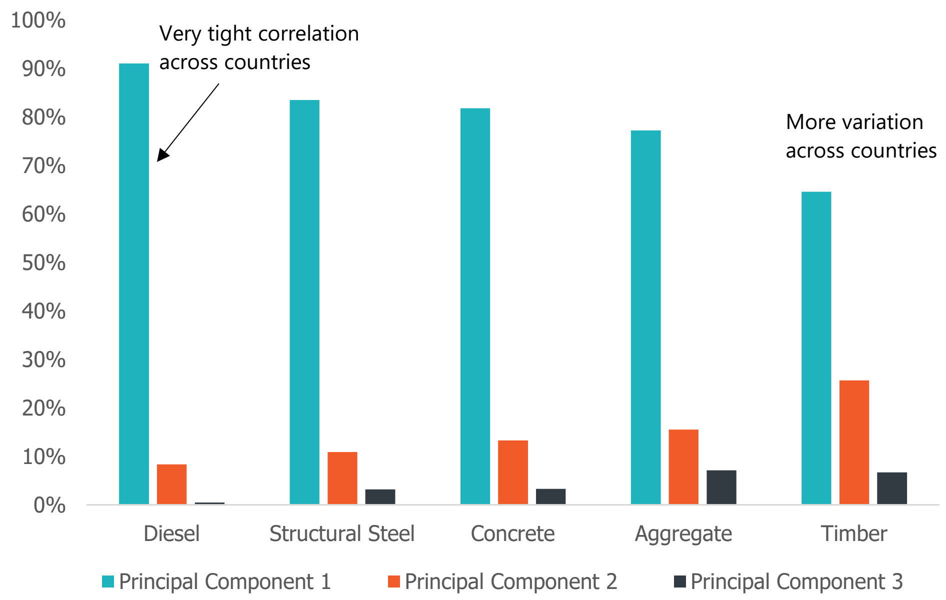
[27] The methodologies for compiling producer price indices vary across countries, as well as the precise definitions of the inputs measured for this analysis. More detail is provided in Appendix B.

[28] In previous research, we found that price levels for most construction inputs are similar between New Zealand and other high-income countries (https://tewaihanga.govt.nz/our-work/research-insights/the-lay-of-the-land-benchmarking-new-zealand-infrastructure-delivery-costs). The main exception was concrete, which is characterised by more localised markets.

To formally test how strong these correlations were across all four countries, we use a technique called Principal Component Analysis to identify patterns within each input. This creates a moving average of all countries' data for each input, called a principal component, and determines how well that component explains the variation between countries. If we find that the variation of prices can be explained largely by a single component, it is a sign that price movements are highly correlated.

Figure 6 shows that for all five construction materials, patterns in price fluctuations are strongly explainable by a single component. This is particularly the case for diesel and structural steel and less so for aggregates.[29]

Figure 6: Principal Component Analysis of Input Prices



Construction materials that are more tradeable tend to have higher price volatility

Figure 7 shows how volatile construction material prices are in each of these countries, as measured by the standard deviation in annual price growth since 2010. Price volatility is highest for diesel, which is the most tradeable construction input, followed by timber and structural steel. Price volatility is lowest for concrete and aggregate, which are the least tradeable inputs.

Since 2010, New Zealand has experienced slightly less construction material price volatility than Australia, the United States, or the United Kingdom. This result may seem counterintuitive, as we are a small country that imports many of these items, making us more exposed to global price fluctuations. One possibility is that New Zealand's scale could create a less competitive input market at the wholesale or retail level, leading to less price volatility overall.

[29] Timber's first principal component (PC1) explains the least variation but that is primarily due to a small sample that includes highly volatile American lumber prices post-2015. Removing USA from the dataset returns a PC1 of 82% (as opposed to 65%).

Figure 7: Standard Deviations in Year over Year Input Price Growth since 2010

3.2 Our approach to explaining construction material prices

Our analysis of movements in construction material prices is motivated by two key questions.

1. **Are there short-run or long-run relationships between construction material prices and broad national factors**, like employment growth or growth in gross fixed capital investment, a proxy for investment in buildings and infrastructure? Do these relationships vary for different types of construction materials?

2. **Are there short-run or long run relationships between construction material prices in New Zealand and global factors such as commodity prices or exchange rates?** When material prices increase in New Zealand, does that simply reflect global price movements? When there are sudden changes to these global factors, should we expect the impact on New Zealand's prices to be immediate or more gradual?

We test these questions using econometric analysis in the following section.

3.3 Explaining changes in New Zealand construction material prices

We explore national and global drivers of construction material prices

We take our analysis of price relationships a step further, using a regression model that uses lagged values of the input price along with these foreign and local variables to predict price movements. We are less interested in forecasting material price changes as we are about seeing whether broad local demand or global supply factors will be predictive of price changes.

These models explore the impacts of broad national factors and global factors on material prices. National factors include two proxy variables for construction demand: changes in employment and changes in real (inflation-adjusted) gross fixed capital formation, i.e., New Zealand's level of investment in buildings, infrastructure, and other fixed assets.[30] Global factors include New

[30] Over the last two decades investment in buildings and infrastructure has accounted for slightly more than half of total GFCF. This is split up as follows: Residential buildings: 27% of GFCF; Non-residential buildings: 12%; Other construction (e.g., infrastructure): 13%.

Zealand's real effective exchange rate, global construction material prices, and proxy variables for global economic conditions (GDP growth and inflation). In one case (aggregates), a global price index was not available due to the fact that aggregate is not a widely traded commodity.

Table 5 summarises results from time series econometric models that analyse short-run and long-run drivers of price growth for five key construction materials.[31] These models are explained in further detail in Appendix C. In **Table 5**, we highlight in bold relationships that are statistically and economically significant. In all models, most of the variables are not significant.[32]

While these models help us examine national and global drivers of material prices, they do not perfectly explain material price fluctuations.[33] These models account for almost all variation in diesel prices, around half of variation in steel and timber prices, and a small share of variation in concrete and aggregate prices. This highlights that other, unmeasured factors may play a role in price trends for some construction materials.

[31] Specifically, an autoregressive distributed lag model with an error correction term where appropriate. This model uses lagged values of the construction material prices along with a set of other predictor variables to predict price movements. A fuller explanation of our model along with sensitivity tests and robustness checks can be found in Appendix C.

[32] Some variables are statistically significant but do not have a meaningful economic interpretation given other model results. For instance, in the steel price regression (column 1), the short-run coefficient on GFCF is negative and statistically significant at the 10% level. The long-run coefficient is positive but not statistically significant. Given the rapid speed of adjustment in this model, which suggests that impacts converge to their long-run level in around one quarter, we didn't think the short-run impacts were economically important.

[33] As indicated by R-squared values – an R2 value of 0.5 indicates that a statistical model accounts for 50% of the variation in the outcome variable.

Table 5: Material price responses in response to a 1% change to national and global variables

	Structural steel prices (1)	Timber prices (2)	Concrete prices (3)	Aggregate prices (4)	Diesel prices (5)
National factors					
NZ Gross fixed capital formation	SR: -0.114* (0.064) LR: 0.098 (0.109)	SR: -0.110 (0.172) LR: 0.291 (0.351)	T0: -0.048 (0.054) T1: 0.035 (0.064) T2: 0.072 (0.052)	T0: -0.053 (0.062) T1: 0.020 (0.066)	T0: 0.230 (0.157) T1: -0.114 (0.166)
NZ employment	SR: 0.723 (0.405) LR: -0.105 (0.587)	SR: -0.427 (0.700) LR: 0.615 (1.121)	T0: 0.204 (0.236) T1: -0.039 (0.240)	T0: 0.005 (0.288) T1: -0.158 (0.288)	T0: -0.291 (0.761) T1: -0.348 (0.720)
Global factors					
Worldwide commodity price	SR: -0.356** (0.154) LR: 0.663*** (0.141)	SR: -0.274 (0.147) LR: 0.612** (0.272)	T0: -0.017 (0.029) T1: -0.045 (0.029)	-	T0: 0.617*** (0.045)
Exchange rates	SR: 0.125 (0.086) LR: -0.175 (0.122)	SR: -0.248 (0.197) LR: 0.143 (0.380)	T0: -0.048 (0.064) T1: 0.060 (0.064) T2: 0.071 (0.064)	T0: -0.076 (0.083) T1: -0.057 (0.083)	T0: -0.883*** (0.212)
Global inflation	SR: -0.005 (0.019) LR: 0.020 (0.027)	SR: -0.006 (0.043) LR: 0.095 (0.058)	T0: 0.006 (0.013) T1: 0.034** (0.014) T2: 0.013 (0.014)	T0: -0.009 (0.015) T1: 0.032** (0.015)	T0: 0.057 (0.045) T1: 0.089 (0.046)
Global GDP	SR: 0.367** (0.149) LR: -0.225 (0.205)	SR: 0.419 (0.329) LR: 0.422 (0.511)	T0: 0.226** (0.112) T1: -0.148 (0.128) T2: -0.179 (0.123)	T0: 0.117 (0.118) T1: -0.019 (0.135)	T0: -1.292*** (0.323) T1: 0.051 (0.309)
Speed of adjustment	-0.919*** (0.103)	-0.803*** (0.179)	No cointegrated relationship	No cointegrated relationship	No cointegrated relationship
Percent variation explained	58%	68%	66%	20%	92%

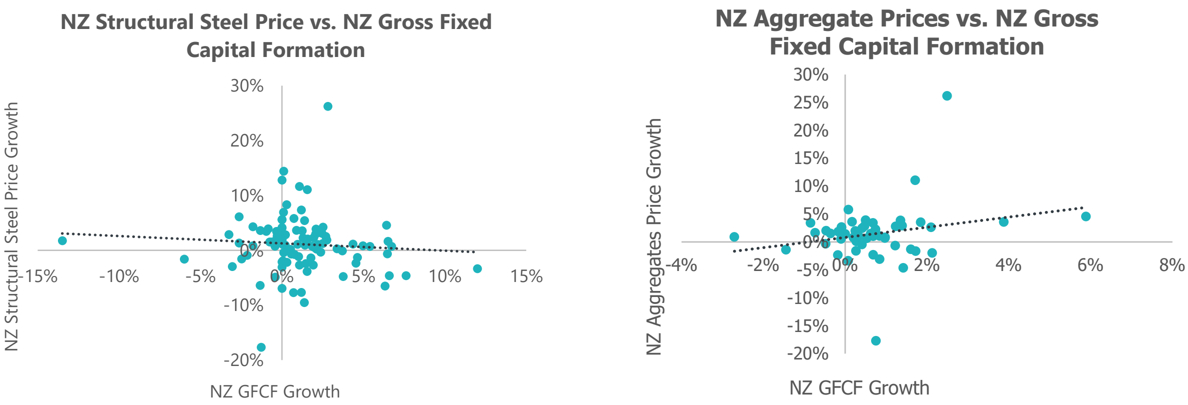
*Note: ***,**,* Denotes statistical significance at 1%, 5%, and 10% level. Figures in parentheses indicate standard errors SR denotes short run, LR denotes long run. For concrete and aggregate, T0 and T1 denote effect in the contemporaneous quarter and one lagged quarter. Results are from autoregressive distributed lag model with an error correction term where cointegration exists. See Appendix C for details.*

Broad national factors do not affect construction material prices

We find that broad national factors like overall investment or employment growth do not play a significant role in determining price changes for material inputs. In all five models, New Zealand-specific variables were statistically insignificant regardless of the time period studied.

Figure 8 illustrates this point for two construction materials (aggregate and structural steel). It shows the correlation between quarterly changes in construction material prices and changes in real (inflation-adjusted) gross fixed capital formation, without controlling for any other variables. The relationship between these two variables is weak and very noisy. This is consistent with our findings from econometric analysis.

Figure 8: Relationships between construction material price growth and local variables



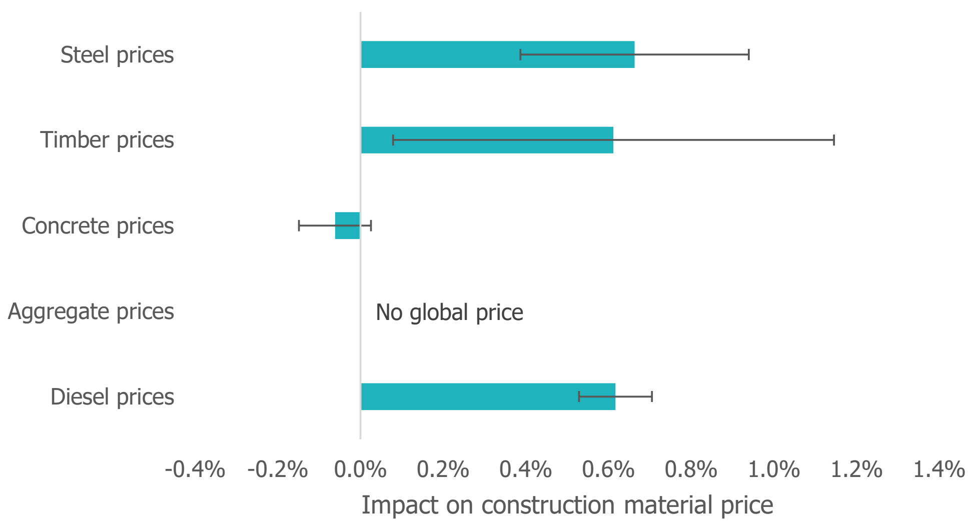
Sources: Te Waihanga analysis of SNZ National Accounts, Producer Price Index, and Capital Goods Price Index data

Global commodity prices are the main influence on prices for tradeable construction materials …

While national factors do not seem to play a role, global commodity prices have a strong impact on prices for globally traded construction materials. This is consistent with our earlier finding that construction price indices move in similar patterns across four high-income countries (see **Figure 6** above).

In particular, we find that changes in world prices for steel, timber, and diesel have a strong, statistically significant impact on New Zealand prices. **Figure 9** shows that a 1% increase in world commodity prices is estimated to lead to a roughly 0.6% increase in New Zealand material prices for all three commodities.[34] By contrast, world cement prices have a small and statistically insignificant impact on New Zealand concrete prices, while we were unable to estimate the impact of world aggregate prices due to the fact that aggregate is not a widely traded commodity.

Figure 9: Impact of a 1% increase in world commodity price on New Zealand material prices



Source: Size of bars reflects magnitude of long-run coefficients (or sum of all quarterly impacts) in the 'worldwide commodity price' row of Table 5. Error bars indicate 95% confidence interval.

[34] In addition, New Zealand's exchange rate has a statistically significant impact on local diesel prices.

… and local prices rapidly adjust to match global prices

For construction materials where there is a strong link between world prices and local prices, local prices adjust rapidly to reflect overall global factors.

Regressions for steel prices and timber prices include convergence factors that reflect how rapidly prices converge back to their equilibrium relationship with other model variables. These convergence factors are large (-0.92 and -0.80, respectively), indicating that almost all convergence happens in around one quarter.[35]

The diesel price regression includes quarterly lagged effects that show how a change in an explanatory variable affects material prices over time. The preferred model only includes a single quarterly effect for world prices (and exchange rates), suggesting that global changes to oil prices are fully passed through to New Zealand in a single quarter.

These results suggest that when there are price spikes in materials exposed to global forces, we should expect prices to match those increase almost contemporaneously. Conversely, if world prices for materials decline, we should expect price relief in New Zealand relatively quickly.

The speed of adjustment appears to be much faster for construction materials than for construction wages. This is consistent with higher levels of price volatility for construction materials, relative to wages (see **Figure 1**).

For non-tradeable commodities, industry-specific or regional factors could play a role

While broad national factors do not appear to influence prices for these five construction materials, our analysis does not rule out that industry-specific or regional factors could affect prices.

This is most likely to be the case for commodities like aggregate and concrete that are produced and used at a local or regional level. Because these commodities are costly and difficult to transport long distances, prices may respond to highly localised factors. For example, aggregate prices may increase due to the fact that new infrastructure projects are far away from existing quarry supplies, resulting in higher transport costs.

Similarly, our analysis focuses on changes in prices, rather than the level of prices. Even for globally traded commodities where local prices move in line with global prices, national, industry-specific, or regional factors could affect the long-run level of prices. For instance, differences in fuel taxes cause fuel prices to be persistently lower in some OECD countries and higher in others, even though changes in prices from quarter to quarter are mainly a function of changes in global oil prices.

[35] A convergence factor of -0.92 indicates that when material prices deviate from their long-run equilibrium, 92% of the gap closes in a single quarter.

4. Conclusion

Building upon recommendation 46 in *Rautaki Hanganga o Aotearoa, the New Zealand Infrastructure Strategy*, this *Research Insights* piece adds to our understanding of cost drivers for construction inputs in the short term. Together, along with our previous work on costs in the construction industry, Te Waihanga has a developed a strong framework for understanding not just whether the *levels* of our costs are comparable to other countries, but also what could be driving *changes or growth* to infrastructure construction costs.

Our key findings

In the short run, construction material prices are more variable than labour cost growth.

Building an infrastructure project requires a mix of labour and materials. We find that material prices are considerably more volatile, displaying price fluctuations of greater than 2% in a single quarter (more than 8% annualised) almost twice the rate of wages. This suggests that if we are interested in explaining why construction prices have changed greatly in the period of a year or two, we should first look to materials.

In the long run, construction wages closely track economy-wide wages…

Inflation-adjusted wages for construction workers have tended to follow wages in the overall economy for the better part of the last 25 years. We explored this relationship using more complex statistical techniques and found evidence of a long-run equilibrium between them. Moreover, we found that construction wages in Australia do not lead to higher or lower construction wages in New Zealand.

This suggests that in the long run, construction wages are more set by the supply of and the demand for labour in the New Zealand economy as a whole, rather than factors specific to the construction market or factors abroad.

…but frictions can cause construction wages to rise faster in the short term.

We found that the pass-through of economy-wide wage to construction wages was not one-to-one. Construction wages also appear to rise faster when the labour market is tighter (as proxied by the share of construction firms reporting labour as a primary constraint on growth).

Convergence back to the long-run relationship between construction and economy-wide wages, while relatively quick, can still take over two years. This suggests that there are some factors that prevent the immediate adjustment of construction wages and could help explain short-term construction cost increases.

For key construction material inputs, prices in New Zealand track global prices movements, but with less volatility.

Looking at the price fluctuations in five key materials for infrastructure construction (structural steel, concrete and cement, timber, aggregates, and diesel fuel), we find that price movements in New Zealand are very similar to those in three other English-speaking countries. Moreover, prices for all construction materials spiked in all four countries following the COVID-19 pandemic, highlighting the global dimension to commodity prices.

We also find that spikes or drops in material prices are less dramatic in New Zealand than other countries for almost all commodities. This result may seem counterintuitive, as we are a small, price-taking country, making us more exposed to global price fluctuations but it's also possible that our scale could lead to competitive input markets at the wholesale or retail level, leading to less price volatility overall.

Global prices, rather than broad New Zealand-specific factors, are the main factor driving price changes for construction materials.

Consistent with our finding that the New Zealand price movements in these materials are similar to other countries, we find that for materials where a global commodity price exists, it is the strongest predictor price fluctuations in New Zealand. This is particularly the case for structural steel, timber, and diesel fuel. Further, our research finds that if there are global spikes in material prices, we should expect our prices to increase almost immediately.

We do not find that increased overall levels of investment or economic activity drive material price fluctuations in the short term. However, this does not rule out the possibility that regional or industry-specific factors may drive price changes.

Implications of our findings

The results of this *Research Insights* piece dovetail with our September and December 2022 papers on construction costs and overall construction sector performance. From this work, we pull some general implications for considering about cost growth and fluctuations in the sector.

Implication 1: We have limited control over input cost fluctuations, especially for materials.

It is difficult to manage short-term price movements for construction inputs. Material price fluctuations are largely determined by global commodity prices which are beyond our control. For labour costs, while tight labour market conditions for construction firms can push up overall construction wage growth in the short term, wage growth is largely a function of overall economy dynamics.

With these insights in mind, there are some targeted, albeit limited, actions we can take to mitigate sharp fluctuations in input costs. These interventions are best suited at a national scale, rather than an agency or project-by-project level.

For materials, central and local governments may benefit from increased direct monitoring of material prices and utilising forecasts of their price to better scope budgets or to determine the timing of the construction phase of a project. Another approach would be to establish long-term price contracts for specific commodities, rather than purchasing materials on a project-by-project basis. This approach, however, would require longer-range project planning and coordination.

For labour costs, market interventions targeted broadly at the construction sector, like construction worker visas, may not have a long-run effect on overall wages. However, our results suggest that they could be useful for filling targeted skill or specific occupation gaps where there is a greater level of frictions (significant training, for instance) preventing easy overall labour market adjustment.

Implication 2: We should target productivity growth to bring costs down in the long run.

While this *Research Insights* piece has highlighted the difficulty of controlling input costs in the short run, our September 2022 report highlighted that if we want to achieve improved cost performance for infrastructure construction, we need to make more with the inputs we do use. That is, we need to increase productivity over time. In that paper, we found that if productivity in infrastructure construction had matched that of building construction over the last 20 years, prices would have been 10% lower, and the quality and quantity of new infrastructure construction would have been 5% higher.

Better yet, there is evidence that we can influence productivity growth. Our research found that at a national level, promoting a more efficient approach to planning, designing, and consenting construction projects could lift productivity. There is also evidence that fostering a competitive construction sector could lead to productivity gains, as firms innovate and improve efficiency to maintain market share. Finally, identifying key skills gaps and experience can improve the capability of the workforce.

On a project level, as evidenced by wind farm construction in New Zealand, we can lift our productivity by learning from past experiences, carefully balancing the introduction of new innovations and the use of standardised technologies and designs.

Implication 3: We can bring costs down through proper planning of scope and design.

If input costs are difficult to control in the short run and enhancing productivity is a long-run path to reducing construction costs, what can be done in the shorter and medium term? Our research from our December 2022 *Research Insights* report highlights the importance of proper project planning. Put simply, we need to know what we are building before we commit to building it.

Our research highlights how poor project planning and problem definition can lead to overengineering and shifting project scope. Poorly planned projects lead construction firms to charge higher prices because of greater scope risk. We have also identified how constantly changing regulations can lead to scope changes and more complex designs to reduce regulatory liability and negative impacts on the environment or communities.

We can influence scope and design costs at a national and project level. Central government-funded projects can be made subject to more rigorous planning frameworks. To mitigate the risk of overengineering projects, each project should face a full evaluation of costs and benefits of scope choice. Finally, adopting a consistent and efficient regulatory environment should be part of a suite of solutions to improve cost efficiency and productivity.

Appendix A: Modelling wage growth in construction

This Appendix explains our modelling approach for wage growth in the construction industry.

Data sources

Main models

The data sources and time periods used for our main regressions can be found in Table A1.

Table A1: Data sources for main market models

Variable	Time period	Source	Table
Hourly earnings (construction and all industries)	1989Q1–2023Q1	SNZ	QEM002AA
Share of businesses reporting 'labour' as their primary constraint (builders and total economy)	1989Q1–2023Q1	New Zealand Institute for Economic Research Quarterly Survey of Business Opinion (QSBO)	N/A
Gross domestic product (construction and all industries)	1989Q1–2023Q1	SNZ	SNE078AA
Consumer price index	1989Q1–2023Q1	SNZ	CPI009AA

For hourly earnings, we used the total earnings measure, which includes both ordinary and overtime wages. We adjusted this using the consumer price index to make all series in constant dollars. Gross domestic product variables are also in constant dollars and seasonally adjusted.

Data on labour constraints is drawn from NZIER's Quarterly Survey of Business Opinion (QSBO). The survey includes a question of businesses in the respective sectors asking about the constraints to growth. Among the possible responses are 'demand', 'labour', 'capacity' and 'supplies'. The measure is in percentages, meaning the percent of respondents who identified labour as the primary constraint to growth.

For our model estimations, the variables for hourly earnings, the QSBO measures, and gross domestic product are logged. This allows for interpretations in our models to be percentage differences.

Cross-Tasman effects model

Our analysis on the effect of Australian economy and construction wages on New Zealand wages required a different set of data sources. The Australian Bureau of Statistics (ABS) does not report an hourly wage figure like SNZ. Instead, the relevant series is average weekly earnings by industry. Table A2 lists the sources, time periods, and frequency of the data used in this model:

Table A2: Data Sources for Cross-Tasman labour market models

Variable	Time period	Frequency	Source	Table
Australia average weekly total earnings, persons	1994H2–2023H1	Biannual	ABS	Table 10i. Average weekly earnings, industry, original – persons, total earnings
NZ average weekly earnings (FTES) by industry	1994Q1–2023Q1	Quarterly	SNZ	QEM007AA
Australia gross value added by industry, chain volume,	1994Q1–2023Q1	Quarterly	ABS	Table 6. Gross value added by industry, chain volume measures
NZ GDP, production measure, chain volume seasonally adjusted ANZSIC06 industry groups	1994Q1–2023Q1	Quarterly	SNZ	SNE078AA
NZ consumer price index	1994Q1–2023Q1	Quarterly	SNZ	CPI009AA
AUS consumer price index	1994Q1–2023Q1	Quarterly	ABS	Tables 1 and 2. CPI: All groups, index numbers and percentage changes

The following transformations were needed to complete the analysis:

- The ABS weekly earnings series is biannual for November and May. In order to have a comparable series for New Zealand, we used the second and fourth quarter observations. For example, the 1995H1 data point in our dataset includes the construction and economy-wide earnings observations for May 1995 for Australia and the 1995Q2 observations for New Zealand.
- The same time matching exercise needed to be completed for the GDP and gross value-added series.
- All earnings series were converted to constant dollars using the respective CPI index observations for the second and fourth quarters depending on whether it was the first or second half of the year.

Methodology

Main models

Our approach to estimating the effect of economy-wide wages on construction involved using two different error correction models.

This approach was motivated by the discovery of cointegration between wages for the construction sector and the economy. Tests for cointegration (using bounds testing (Pesaran, Shin, and Smith, 2001) and Engle-Granger two step method (Engle and Granger, 1987)) showed a cointegrated relationship between construction wages and economy wide wages. These tests were performed on the log-levels of these variables.

Table A3: Test results for cointegration in models 1 and 2

Test-statistic	Model 1 (basic EC model)	Model 2 (ARDL with EC term)
Pesaren/Shin/Smith Bounds Test F-Statistic	…	**3.708***
Engle Granger Test Statistic	**-4.346*****	**-4.691*****

*Note: *,**,*** denotes rejection of the null hypothesis of no cointegration at the 10%, 5% and 1% level.*

We also identified that the series are stationary in differences through Augmented Dickey-Fuller tests.

In our first model (which we call Model 1), we estimated a standard, two-variable error correction model:

$$\Delta x_t = \beta_o + \beta_1 \Delta y_t - \lambda[y_{t-1} - x_{t-1}] - u_t$$

Where x_t represents logged real construction wages at time *t* and y_t is logged real economy-wide wages. λ represents the speed of adjustment between the short and long run model. **We are interested in determining whether $\beta_1$is equal to 1, and the size of λ.** A large β_1 and λ would indicate minimal movement frictions between sectors, suggesting that periods of upward pressure on construction labour costs and construction prices (i.e. periods where construction wage growth is faster than economy-wide wage growth) are usually short-lived.

Our second model (which we call Model 2), an autoregressive distributed lag model with an error correction term, is largely an extension of our first model with additional variables and autoregressive terms.

$$\Delta x_t = \beta_o + \sum_{i=1}^{p} \beta_{1i} \Delta y_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta E\_GDP_{t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta C\_QSBO_{t-i} + \sum_{i=1}^{p} \beta_{4i} \Delta E\_QSBO_{t-i} + \lambda[x_{t-i} - \frac{\sum_{i=0}^{p} \beta_i X_t}{\alpha}] + u_t$$

Where:

- x_t represents logged real construction wages at time *t*
- y_{t-i} is logged real economy-wide wages at time *t-i*
- E_GDP_{t-i} is logged real economy-wide GDP at time *t-i*
- C_QSBO_{t-i} is the logged QSBO measure of the share of construction firms reporting labour as their primary constraint at time *t-i*
- E_QSBO_{t-i} is the logged QSBO measure of the share of all firms reporting labour as their primary constraint at time *t-i*
- X_t is a vector of the variables above
- λ is the adjustment term between the long and short run.

For lag order selection, we used the Schwarz information criteria.

Cross-Tasman models

We were also interested examining whether construction or economy-wide wages in Australia were determinative of wages in New Zealand. We hypothesised that there could be a single labour market for construction workers between the two countries. If this were the case, we would see a strong relationship between the two wages as we did for New Zealand economy-wide wages.

We first find that there does not appear to be a cointegrated relationship between logged real construction weekly earnings in New Zealand and Australia.

Table A4: Engle-Granger Two-Step Test statistics for cointegration

Variable	NZ construction weekly earnings	NZ economy-wide weekly earnings
Australian construction weekly earnings	-2.694	-1.725
Australian economy-wide weekly earnings	**-3.273***	-1.814

*Note: * denotes rejection of the null hypothesis of no cointegration at the 10% level.*

We tested further to see if there is cointegration between the groups of variables we considered for our two eventual models.

- Cross-Tasman model 1: Logged real New Zealand construction weekly earnings as a dependent variable. New Zealand economy-wide earnings, Australian construction weekly earnings, and Australian economy-wide weekly earnings as the independent variables.
- Cross-Tasman model 2: Same variables as Cross-Tasman model 1 but would include controls for real output in New Zealand's construction sector and economy.

Table A5: Cointegration tests for Cross-Tasman models

Test-Statistic	Cross-Tasman model 1	Cross-Tasman model 2
Pesaren/Shin/Smith Bounds Test F-Statistic		2.591
Engle Granger Test Statistic	**-4.428****	-4.544

*Note: *, ** denotes rejection of the null hypothesis of no cointegration at the 10% and 5% level.*

We find evidence of cointegration for the variables in the first model. For the second model, the Bounds test revealed inconclusive results while the Engle Granger test did not reject no cointegration but at just outside the 10% level.

Because these tests showed cointegration (albeit weak evidence), we used two models very similar to our New Zealand labour market models to test the relationship between Australian construction worker earnings with their New Zealand counterparts:

- Our first model is a standard error correction model like our main Cross-Tasman model 1 above. It includes logged New Zealand construction sector weekly earnings as the dependent variable. The independent variables are logged real New Zealand economy-wide weekly earnings and logged real Australian construction and economy-wide earnings. Because the model is run with differences, the results are determined as percentage changes or growth.
- Our second model is an autoregressive distributed lag model with an error correction term that builds upon the model above by adding controls for Australia and New Zealand real GDP growth.

Full model results are available below in **Table A6.**

Table A6: Australian labour market effects on New Zealand construction earnings

Biennial changes in construction weekly earning in response to a 1% change in variable				
	Cross-Tasman model 1		**Cross-Tasman model 2**	
	Coefficients	**Std Errors**	**Coefficients**	**Std Errors**
Short-run model				
NZ economy-wide weekly earning	1.191***	0.228	1.105***	0.378
Lagged 6 months			0.546	0.371
Lagged 12 months			-0.078	0.319
AUS construction weekly earnings	-0.16**	0.073	-0.095	0.084
AUS economy-wide weekly earnings	0.143	0.179	-0.274	0.284
NZ construction GDP			-0.002	0.113
Lagged 6 months			-0.005	0.108
Lagged 12 months			0.078	0.049
NZ overall GDP			0.068	0.27
Lagged difference			0.262	0.248
Long-run model				
NZ economy weekly earnings			0.268	0.861
Australian construction weekly earnings			0.006	0.291
Australian economy-wide weekly earnings			1.11	0 776
NZ construction GDP			0.535	0.442
NZ overall GDP			-0.965	0 686
Convergence speed	-0.550***	0.003	-0.317*	0.172
R-squared	0.47		0.57	

*Note: ***,**,* Denotes statistical significance at 1%, 5%, and 10% level. Data frequency are half year. Convergence speeds are interpretable as percent of a shock closed in six months.*

Diagnostics and robustness testing

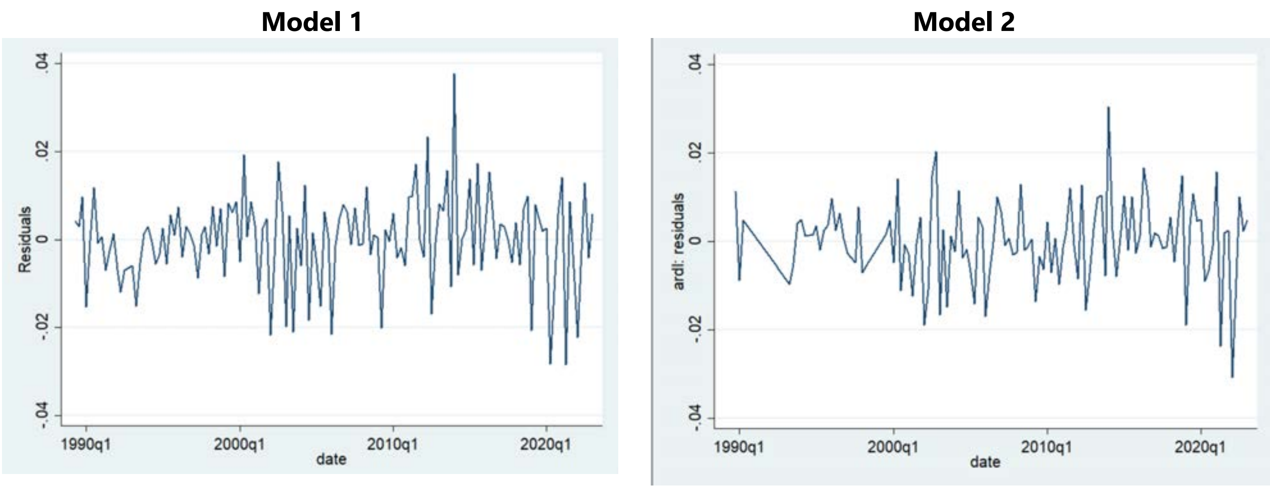
Diagnostics

The primary concern for both our New Zealand labour-market models was serial correlation of the error terms. Autocorrelation plots did show a high degree of autocorrelation between the logged level of the two main variables but not for the differences.

Figure A1: Models 1 and 2 autocorrelation plots

Plotting the residuals for both model 1 (two-variable ECM) and model 2 (ARDL with ECM) show the errors are not strongly correlated across time periods, although model 2's residuals seem to suggest there could be some correlation.

Figure A2: Residual plots for labour models 1 and 2



A Durbin-Watson test for first order serial correlation resulted in the following d-statistics (k,n):

- Model 1: 2.37 (3,136)
- Model 2: 2.17 (16, 118)

These results show that there is evidence of negative serial correlation in both models, but the test statistics fall between a range of 1.5 and 2.5 meaning the correlation is somewhat weak, which mitigates our concerns.

Robustness tests

The following specifications were tested as robustness checks to our main models. The full results can be found in **Table A7** below.

- **Robustness model 1:** *Substituting construction GDP for economy-wide GDP*: Model 2 controls for overall economic conditions by including economy-wide GDP. Since our dependent variable is construction wages, we specified a different model that used construction GDP instead of overall GDP. We find that the coefficient on economy-wide wages becomes large and strongly significant in the long run model (compared to model 2 where it was not statistically significant). This suggests that omitting overall GDP growth from our model biases the coefficient on economy-wide wage growth. This specification also explains less variation than model 2.

- **Robustness model 2:** *Using a vector error correction model (VECM):* Model 2 is an ARDL model with an error correction term. We test the result of this model by comparing it to a VECM. The VECM allows for all variables in the model to act as a system. While the VECM creates equations for all variables in the system, we focus our attention primarily on the vector with construction wages as the dependent variable.

    - The variables in the VECM are the same as model 2. The time period studied is slightly different. The NZIER QSBO responses included some gaps between 1989 and 1999. Use of the VECM does not allow for gaps in the data (from 1989 to 1999), so the model is run on the time period 1999Q1 through 2023Q1 (as opposed to 1989Q1 to 2023Q1 for models 1 and 2).
    - The VECM results show some notably different results, primarily in the short-run model. No coefficient is statistically significant in the short-run model whereas economy-wide wage growth, and QSBO labour market tightness are in model 2. In the long-run model, the VECM again finds no predictive ability of economy-wide wages on construction wages. It does however find that overall GDP growth is strongly predictive (like model 2) and that QSBO labour market tightness in construction has a negative effect on construction wages (also like model 2 but to a larger degree).
    - Another notable difference between model 2 and the VECM specification is that the convergence factor is considerably smaller in the VECM. The convergence factor suggests that a shock is 90% dissipated over the course of about six years (compared to 2 years in model 2).
    - We report the ARDL-EC as our main model for a few reasons. We consider these differences to be primarily the result of the VECM attempting to use the inputted variables to explain a system of interactions amongst the variables, rather than the ARDL which attempts to explain variation for a single dependent variable. A Johansen trace test for cointegration (Johansen, 1988) found that there was only one cointegrating equation amongst the system of five variables. We therefore consider that the ARDL model with an error correction term to still be appropriate. Further, we find that not all variables in the model are I(1) (QSBO measure of construction labour is I(0), so we deem the ARDL process as valid.

- **Robustness model 3:** *Including a population term*. Economic theory would suggest that the demand for labour in either construction or the economy is a function of population growth. We included a measure of New Zealand population growth (the first difference of logged population) in our model. We find that population growth is not predictive of construction wage growth, at least in the short term.

All results from our robustness tests can be found in **Table A7.**

Table A7: Alternative labour model specifications

	Model 1		Model 2		Robustness model 1		Robustness model 2 (VECM)		Robustness model 3 (w/population)	
	Coefficients	Std Errors	Coefficients	Std Errors	Coefficients	Std Errors	Coefficients	Std Errors	Coefficients	Std Errors
Short-run model										
Real economy-wide wage	0.733***	0.129	0.594***	0.152	0.542***	0.16	0.044	0.206	0.825***	0.147
QBSO: Difficulty finding construction labour			0.008***	0.003	0.006**	0.003	0.005	0.003		
Lagged one quarter			0.005***	0.002	0.004*	0.002				
QSBO: Difficulty finding labour economy-wide			-0.003	0.005	-0.003	0.005	-0.002	0.006		
Overall GDP			0.028	0.067			0.063	0.078		
Lagged one quarter			0.100*	0.117						
Construction GDP					-0.002	0.021				
Lagged one quarter					0.007	0.018				
Population									0.595	0.549
Long-run model										
Real economy-wide wage			0.257	0.397	0.831***	0.356	0.097	0.646		
QBSO: Difficulty finding construction labour			-0.040**	0.018	-0.035*	0.021	-0.125**	0.02		
QSBO: Difficulty finding labour economy-wide			0.009	0.172	0.019	0.022	0.076***	0.023		
Overall GDP			0.467**	0.178			0.579*	0.298		
Construction GDP					0.139	0.105				
Convergence factor	-0210***	-0210***	-0206***	0.064	-0.181***	0.065	-0.077**	0.029	-0.227***	0.058
Adjusted R-squared	0.22		0.32		0.24		0.24		0.23	

Note: Coefficients for the VECM are lagged difference for the short run model.

Directional effects

Our modelling primarily focused on the adjustment of the construction sector in response to changes in economy-wide wages. Construction is the smaller sector making it more likely, at least in theory, to be the sector that adjusts. That being said, swapping the dependent and independent variables in the same error correction model does suggest that that economy-wide wages may be somewhat responsive to construction wages (**Table A8**).

Table A8: Labour market adjustments in error correction models

Quarterly changes in construction wages in response to a 1% changes the following variables

	Primary model		**Alternative**	
	Dependent variable: Construction wage growth		**Dependent variable:** Economy-wide wage growth	
	Coefficients	**Std errors**	**Coefficients**	**Std errors**
Real economy-wide wage	0.733***	0.129		
Construction sector wage			0.265***	0.047
Convergence factor	-0.210***	0.054	-0.136***	0.042
R-squared	0.24		0.20	

*Note: ***,**,* Denotes statistical significance at 1%, 5%, and 10% level.*

Appendix B: New Zealand price inflation in the global context

This appendix explains the data used for international comparisons of price growth for key heavy construction materials.

Data sources

Data for this analysis is drawn from other country input producer price indices. Data sources can be found in **Table B1**.

Table B1: Data sources for construction materials across countries

Country	Source	Index	Table
New Zealand	Statistics New Zealand	Capital goods price index, producer price index input series	CGPI: CEP008AA PPI: PPI029AA
United States	Bureau of Labour Statistics	Producer price index: commodity series	WPS series[36]
Australia	Bureau of Statistics	Producer price index	Inputs to the house construction industry, outputs for petroleum manufacturing[37]
United Kingdom	Office of National Statistics	Producer price index time series	MM22[38]

We matched series across the five commodities: structural metal products, aggregates, diesel, timber, and concrete. The precise detail of what is included in each definition were not readily available and we recognize that these series may have measurement differences. **Table B2** identifies the name of the series used from each country.

[36] https://www.bls.gov/ppi/databases/
[37] https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/producer-price-indexes-australia/latest-release
[38] https://www.ons.gov.uk/economy/inflationandpriceindices/datasets/producerpriceindex

Table B2: Series used and matched to NZ PPI inputs for heavy construction across countries

Colloquial name	New Zealand	United States	Australia	United Kingdom
Structural steel	Structural metal products and parts thereof	Fabricated structural metal	Steel beams and sections	Structural metal products for domestic market
Concrete	Articles of concrete, cement, and plaster	Concrete products	Concrete, cement, and sand	Concrete, cement and plaster for domestic market
Diesel	Diesel	Diesel	Outputs of refined petroleum and petroleum manufacturing	Refined petroleum products for domestic market
Timber	Timber and timber	Lumber	Timber: board and joinery	Timber, sawn and planed for domestic market
Aggregate	Aggregates	Construction sand, gravel, and crushed stone	No series	Stone, sand, and clay for domestic market

Data availability by years is shown in **Table B3.**

Table B3: Data availability across countries

Input	New Zealand	United States	Australia	United Kingdom
Structural steel	1996Q4-2022Q3	2005Q1-2023Q2	1985Q3-2023Q1	2009Q1-2023Q1
Concrete	2009Q4-2023Q1	1985Q1-2023Q2	1985Q3-2023Q1	2009Q1-2023Q1
Diesel	2009Q4-2023Q1	1985Q1-2023Q2	1985Q3-2023Q1	2009Q1-2023Q1
Timber	2009Q4-2023Q1	1985Q1-2023Q2 with gaps (2011-13, 2004-5, 1991-96)	1985Q3-2023Q1	2009Q1-2023Q1
Aggregate	2009Q4-2023Q1	1985Q1-2023Q2	No series	2009Q1-2023Q1

Principal component analysis

To determine how tightly correlated price movements were across countries for the five main inputs, we used principal component analysis. This analysis required all countries to have data in the analysed periods. For most inputs, the analysis period is 2009Q4 through 2023Q1 since all countries generally have data for this period. For timber, the data period is 2013 through 2023Q1 since the US series has gaps. We find similar results for timber when we exclude the US from the dataset.

Appendix C: Short-term price drivers for material prices in New Zealand

In this appendix, we lay out our methodology for estimating the impact of domestic and foreign variables on short term input price movements in New Zealand.

Data sources

For modelling short term price fluctuations in material prices, the time periods studied depended upon the availability of input price data. **Table C1** lists the sources and time periods studied for each key input. For most series, the time period studied is 2009Q4 to 2023Q1 (except concrete which starts at 2010Q1), but for structural steel, it was 1997Q1 through 2023Q1.[39]

Table C1: Data sources used for material prices

Variable	Time period modelled	Source	Table
Structural metal products and parts thereof (structural steel) capital goods price index	1997Q1–2023Q1	SNZ	CEP008AA
Articles of concrete, cement, and plaster, published input commodities, producer price index	2009Q4–2023Q1	SNZ	PPI029AA
Aggregates, published input commodities, producer price index	2009Q4–2023Q1	SNZ	PPI029AA
Diesel, published input commodities, producer price index	2009Q4–2023Q1	SNZ	PPI029AA
Timber and timber, published input commodities, producer price index	2009Q4–2023Q1	SNZ	PPI029AA

All indices are reindexed to 2009Q1, and log transformed.

For proxies of worldwide commodity prices, we took two approaches. For the diesel and timber models, we pulled data from International Monetary Fund's Primary Commodity Price database.[40] This database contains price indices for the global primary commodity. We considered these price indices closest to the globally traded price of these two inputs. The indices specifically used for diesel and timber were:

- **Soft timber:** index, measured in USD per cubic meter, U.S. state of Oregon lumber and logs.
- **Spot crude petroleum:** index, measured in USD per barrel, West Texas Intermediate.

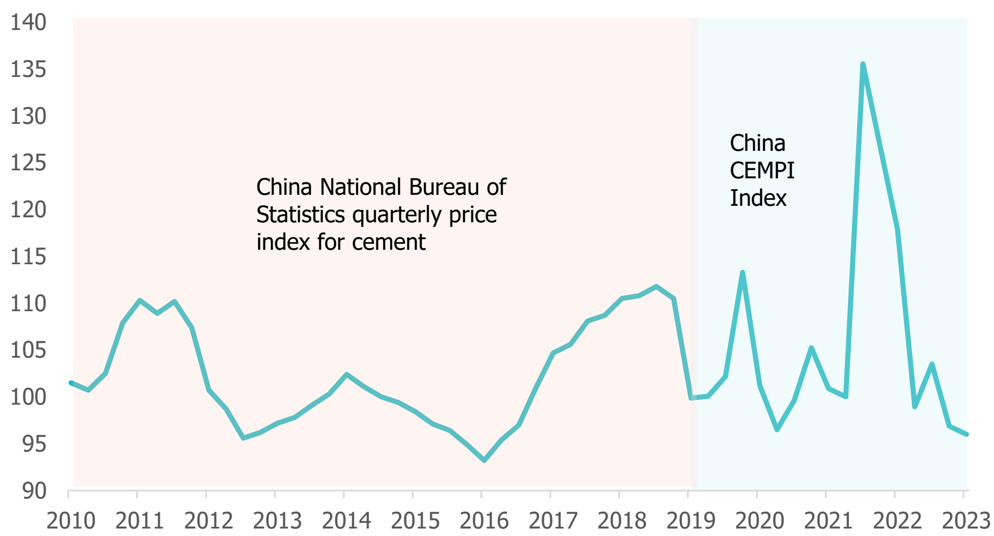
[39] Materials using the Producer Price Index were updated in September 2023 to reflect SNZ corrections to historical data during the August 2023 release.
[40] https://www.imf.org/en/Research/commodity-prices

For cement and structural steel, the input used to construction is further down the production chain than the primary commodity. As such, we created two of our own indexes for these commodities to proxy for a global price.

- **Cement Price Index:** In the absence of a globally traded cement commodity price, our approach was to use the price of cement in China as a proxy for global cement prices. China produces and consumes, by a wide margin, the largest amount of cement in the world, with some estimates suggesting it produces 60% of the world's cement.[41] We posit that movements in the Chinese price for cement closely mirror those of prices around the world.

The Chinese National Bureau of Statistics (NBS) produces a quarterly price index for cement running from March 2010 through December 2018. [42] We combine this series with the growth of the Chinese CEMPI index, which also tracks the price of cement in China.[43] We utilise the NBS series from 2010 through 2018 and then splice the series with the growth rate of the CEMPI from March 2019 through March 2023.

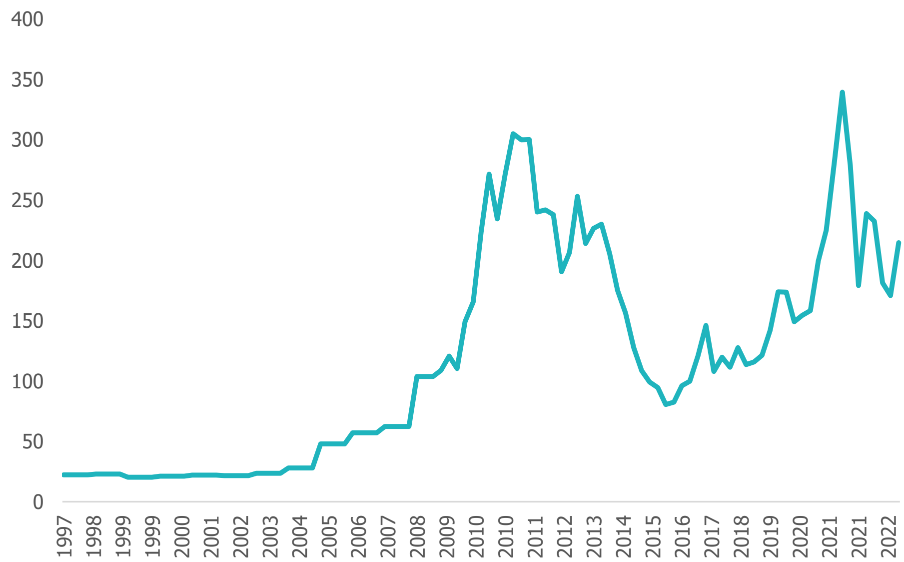
Figure C1: Chinese cement series used for concrete and cement models



- **Steel Price Index:** While the IMF commodity database does contain a series for Iron Ore, structural steel is at least two stages down the production chain (raw steel, then fabricated steel). We were also concerned that iron ore prices were very flat prior to 2004.

[41] https://arc-group.com/asia-cement-industry/
[42] https://data.stats.gov.cn/english/easyquery.htm?cn=B01
[43] https://index.ccement.com/index.html

Figure C2: IMF Iron Ore Price Index

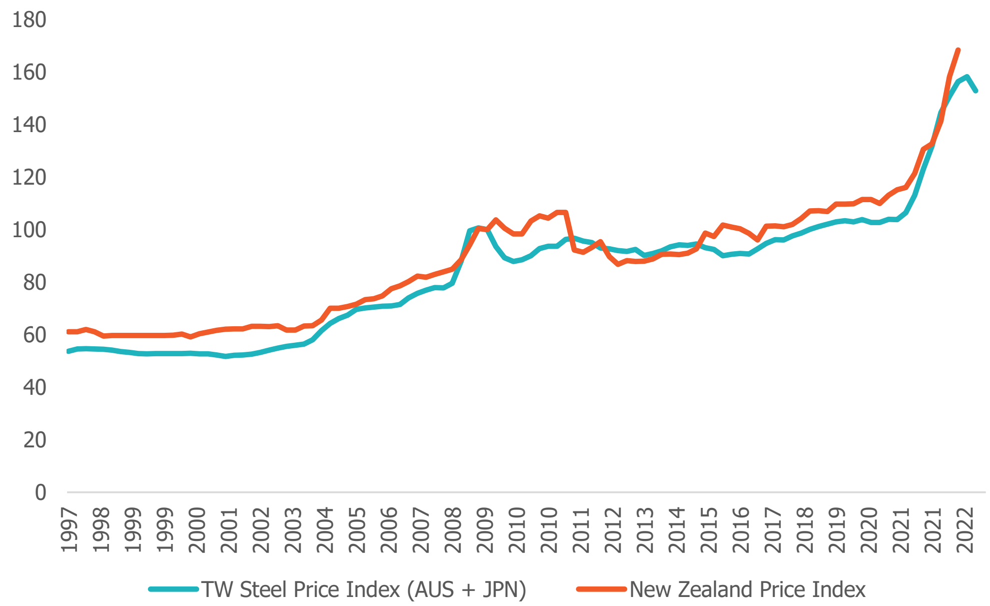


Source: International Monetary Fund, Primary Commodities Database

We created our own steel price index by gathering producer price indices for fabricated or structural steel across several countries. Our chosen steel price index is simply an average of structural steel prices in Australia and Japan. This approach was chosen because first, Australia and Japan were the nearest countries we could find that had price index observations going back to 1997, which is the first observation for New Zealand. Second, even in the later years with additional countries added to the average (US beginning in 2005 and UK added in 2009), we find very similar trendlines to the Australia and Japan average. In other words, adding more countries to the average did not add much additional information. This result is reinforced by the strong explanatory power of the first principal component in our PCA analysis for structural steel.

Our created series runs from 1997Q1 through 2023Q1, and at first glance, displays a strong correlation with New Zealand's structural steel price index **Figure C3**.

Figure C3: Index of Australian and Japan Structural Steel Prices (2009Q1=100)



Finally, for aggregates, we deemed there was not likely to be global demand price. Most aggregate is quarried locally for infrastructure construction.

We also constructed a series for world GDP at quarterly frequency to match our price series.[44] We undertook the following steps to create the series:

- Using quarterly data from the IMF International Financial Statistics database,[45] we pulled the GDP series for the United States, China, the Euro Area, Japan, India, the United Kingdom, Canada, and Brazil in their national currencies.
- We converted these series to U.S. dollars using quarterly average exchange rates.
- We summed across countries and indexed to the first quarter of 1997.

Together these countries combined for a GDP of at approximately $70 trillion in 2021. World Bank estimates had world GDP at approximately $96.88 trillion that year, so we estimate our series accounts for roughly 70% of total GDP.

Sources of data for our other variables are as follows:

- Effective exchange rates: Bank for International Settlements effective exchange rates, weighted by trade partners.[46] This is measured as an index.
- Gross Fixed Capital Formation: Statistics New Zealand, National Accounts expenditure measure, seasonally adjusted, constant prices (Table SNE037AA).
- Employment: Statistics New Zealand, Household Labour Force Survey, seasonally adjusted (Table HLF096AA).
- Global inflation: G20 inflation from the Organisation for Economic Cooperation and Development (OECD).[47] This series is in growth rates, rather than an index.

All series were log-transformed prior to model estimation.

[44] Most readily available series on world GDP are at the annual frequency (World Bank).
[45] https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b
[46] https://www.bis.org/statistics/eer.htm
[47] https://data.oecd.org/price/inflation-cpi.htm

Methodology

Our theoretical construct for our modelling approach is that that the price of a material input is a function of factors that will affect the supply and demand of that input. These factors will be local and global in nature.

- For demand, we expect that New Zealand investment levels (proxied by gross fixed capital formation) and strong economic fundamentals (New Zealand employment) will put upward pressure on prices.
- For supply, we expect that global commodity prices and exchange rates will exert an effect on material prices, particularly for imported goods.
- We believe that world GDP and inflation will have an effect on input prices in New Zealand, but we include them primarily as controls. We had no expectation of the signs of their coefficients.

For each of the five materials, we estimate a form of the following equation:

$$\Delta y_t = \beta_o + \sum_{i=1}^{p} \beta_{1i} \Delta NZ\_GFCF_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta NZ\_REER_{t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta NZ\_Employ_{t-i} + \sum_{i=1}^{p} \beta_{4i} \Delta Comm\_Price_{t-i} + \sum_{i=1}^{p} \beta_{5i} \Delta W_{t-i} + u_t$$

Where:

- y_t represents quarterly change in the material price *t*
- NZ_GFCF_{t-i} is the quarterly change in New Zealand investment rate at time *t-i*
- NZ_Employ_{t-i} is the quarterly change in New Zealand employment at time *t-i*
- NZ_REER_{t-i} is the quarterly change in the effective exchange rate at time *t-i*
- $Comm\_Price_{t-i}$ is the quarterly change in the relevant worldwide price index for that material at time *t-i*
- W_{t-i} is a vector of control variables representing worldwide inflation and GDP at time *t-i*.

We expect investment and employment to have a positive sign and exchange rates to have a negative coefficient, particularly for highly imported goods like diesel. We also expect the worldwide commodity price to be positive and highly predictive.

We began our approach by determining that all input series and all foreign and domestic variables contained unit roots in levels through the Augmented Dickey Fuller Test. The variables become nonstationary in first differences. As such, all models were run with the variables in first difference.

Moreover, we found that some of the series in the model displayed some evidence of cointegration (structural steel and timber). These tests were run on the logged levels of the variables.

Table C2: Cointegration tests for materials models

Test-Statistic	Structural steel	Timber	Concrete	Aggregate	Diesel
Pesaren/Shin/Smith Bounds Test F-Statistic	**3.903****	2.779	2.814	0.957	2.065
Engle Granger Test Statistic	-4.364	**-4.823***	-3.58	-3.606	-3.971

*Note: *, ** denotes rejection of the null hypothesis of no cointegration at the 10% and 5% level.*

For these variables, a generalised error correction model was estimated.

$$\Delta y_t = \beta_o + \sum_{i=1}^{p}\beta_{1i}\Delta NZ\_GFCF_{t-i} + \sum_{i=1}^{p}\beta_{2i}\Delta NZ\_REER_{t-i} \\ + \sum_{i=1}^{p}\beta_{3i}\Delta NZ\_Employ_{t-i} + \sum_{i=1}^{p}\beta_{4i}\Delta Comm\_Price_{t-i} + \sum_{i=1}^{p}\beta_{5i}\Delta W_{t-i} + \lambda[x_{t-i} - \frac{\sum_{i=0}^{p}\beta_i X_t}{\alpha}] + u_t$$

Where:

- y_t represents quarterly change in the material price t
- NZ_GFCF_{t-i} is the quarterly change in New Zealand investment rate at time *t-i*
- NZ_Employ_{t-i} is the quarterly change in New Zealand employment at time *t-i*
- NZ_REER_{t-i} is the quarterly change in the effective exchange rate at time *t-i*
- $Comm\_Price_{t-i}$ is the quarterly change in the relevant worldwide price index for that material at time *t-i*
- W_{t-i} is a vector of control variables representing worldwide inflation and GDP at time *t-i*
- X_t is a vector of the variables above
- λ is the adjustment term between the long and short run.

The variables were logged and estimated in first differences. In this model, the coefficients on $\beta_1$through β_5 are the estimates of the short-run effect. β_i is the estimate of the long-run effect. λ is the speed of adjustment between the short and long run models. Because the evidence of cointegration was relatively weak, we expect that the coefficient for the speed of adjustment to be relatively large.

Similar to our modelling for labour wage changes, we adopted an autoregressive distributed lag model (ARDL) as our preferred approach to understanding price changes in inputs.

- Theoretically, we consider most of the variables in this regression to be exogenous, particularly foreign variables. We would not expect New Zealand GDP, gross fixed capital formation, input prices, or employment to impact any foreign variable in this model, as New Zealand is a small economy. While we acknowledge that input prices could have a dampening effect on investment and employment, we assume New Zealand variables would have a one-way directional effect: input prices are affected by investment, GDP, or higher employment levels.[48]
- The use of a one-equation ARDL model allows for modestly easier interpretability of results.

We select the appropriate lag lengths using the Schwartz information criteria. The lags used in all equations are reported below:

Table C3: Selected Lag Lengths for Variables in Material Price Models

Variable	Structural steel prices	Timber prices	Concrete prices	Aggregate prices	Diesel prices
Dependent	1	1	1	1	1
Exchange rates	1	1	2	1	0
NZ employment	1	1	1	1	1
Worldwide commodity price	2	2	1	N/A	0
NZ GFCF	1	1	2	1	1
Global inflation	1	1	2	1	1
Global GDP	1	1	2	1	1

[48] To test this, in our subsequent robustness testing, we used a series of basic vector autoregressions as a first approximation to our ARDL models. Granger Causality tests found that generally, input prices were not predictive of any New Zealand specific variable.

Robustness and sensitivity testing

Diagnostics

Like our labour models, we were primarily concerned about serial correlation of the error terms. We tested for this using the Breusch-Godfrey[49] test for higher-order serial correlation and found some evidence that there could be serial correlation in our timber model, but not in the others.

Table C4: Breush-Godfrey Tests and P-Values Serial Correlation in Materials Models

	Structural steel	Concrete	Timber	Aggregate	Diesel
Breusch-Godfrey P-Value	0.1450	0.6977	**0.0656***	0.9008	0.7937

Note: Denotes rejection of the null hypothesis of no serial correlation at the 10% level.

First order serial correlation tests found Durbin Watson test statistics all within an acceptable range.

Robustness checks

Using a measure of New Zealand GDP growth instead of employment growth: We find that like employment, including New Zealand GDP has no effect on the price growth of these inputs in the short term.

- **Including New Zealand interest rates, as proxied by the 30-day bank bill yield rate:** Interest rates could be a measure of financial conditions in the country, representing a potential supply shock. Across all input models:
  - including interest rates in our models improves model fit only slightly
  - the coefficients for the interest rate are small and positive, but not statistically significant[50]
  - the coefficient on gross fixed capital formation generally becomes smaller and modestly more significant.

Based upon these results, we suspect that rather than proxying for financial conditions, the inclusion of interest rates was a proxy of economic activity or inflation in New Zealand. This was particularly problematic because it makes interpretations of gross fixed capital formation, our preferred measure of demand for infrastructure, more difficult. For these reasons, it was excluded.

- **Excluding gross fixed capital formation:** We find that excluding gross fixed capital formation worsens the fit of the models without providing any more explanatory power for the remaining variables.
- **Structural Vector Autoregressions in lieu of ARDL:** We also tested the robustness of our results by specifying a series of structural vector autoregressions (SVAR) for each input price with the variables in logged first-differences.

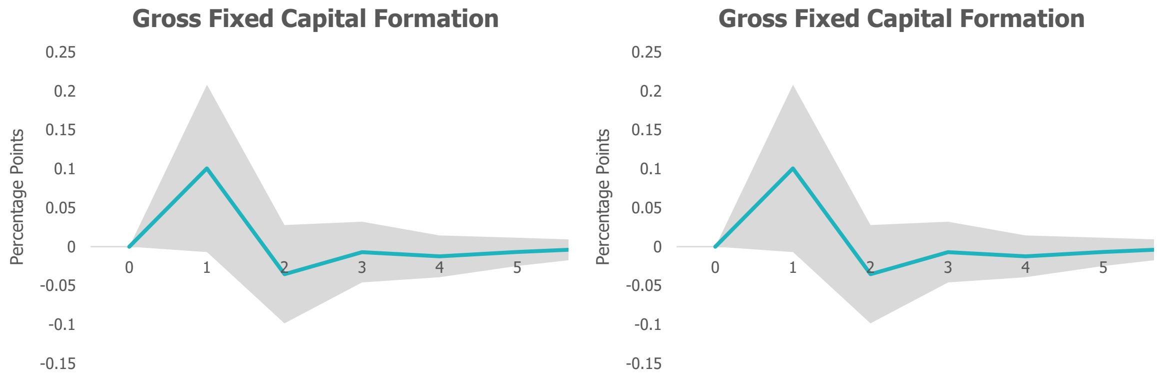
In our SVAR specifications, we used a combination of theory and Granger Causality tests to place restrictions on the model to ensure shocks have the correct theoretical directional effects. Our key set of restrictions in each SVAR is that all foreign variables (world GDP, world inflation, and traded commodity prices) are treated as exogenous. Within the system, New Zealand variables (input price indices, employment, and gross fixed capital formation) are restricted from having an impact on foreign variables.

[49] Godfrey, L. G. 1978. Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables. Econometrics 46: 1293–1301.

[50] This is somewhat counterintuitive as we expect interest rates to have a negative sign. This might be because higher interest rates are proxying for periods of higher inflation during periods of stronger economic growth. As a result, they may be acting as a demand-side variable rather than a supply-side variable.

In general, the results of our SVAR regressions show broadly similar impacts as our ARDL models. For example, the following charts show impulse response functions for structural steel prices in New Zealand.

Figure C4: Structural VAR Impulse Response Functions for NZ Structural Steel Prices



The structural steel SVAR finds that a standard deviation shock to gross fixed capital formation is positively associated with and increase in structural steel prices growth by about 0.1 percentage points but with a high degree of uncertainty and the effect dissipates quickly. Likewise, it finds that a shock to global steel prices is linked to a strong positive impact on structural steel prices in New Zealand. SVAR provides additional insight, finding a shock to global steel price raises steel prices in New Zealand for a sustained period (for over a year).

Our ARDL model results in **Table 5** in the body of the report largely agree with these two results in direction and to a lesser degree, magnitude. Gross fixed capital formation has a small negative impact in the short run model, which is defined as the period within a quarter. The effect of global steel prices is strongly positive in the period after about a quarter. The SVAR, unlike our ARDL below, does not include an error correction term (i.e., a vector error correction model) so there is no distinction between the short and long run models for the SVAR.

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